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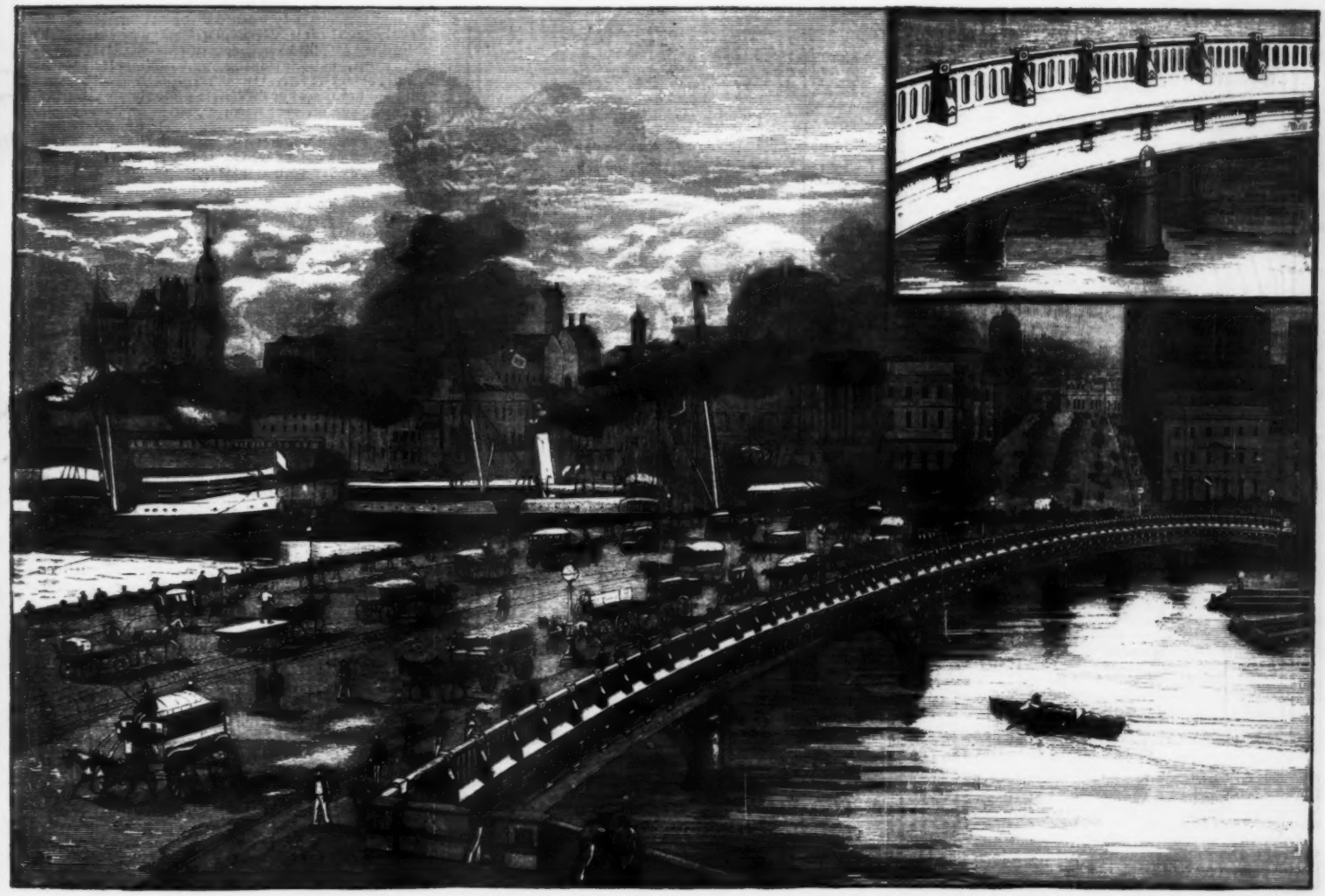
THE QUEEN'S BRIDGE.

THE completion of the new Prince's Bridge, which forms so fine an approach to the heart of Melbourne from most of the southern suburbs, has just been followed by the opening of a structure that will be in harmony with it, to replace what was known as "The Falls Bridge." The "falls" having disappeared soon after the old bridge itself, a new name was sought for the recently finished work, and the title of "The Queen's Bridge" was selected. The new bridge, which abuts on the foot of Market street, will be in keeping with the improvements already effected and now in progress on the city banks of the Yarra. It is of great width, fully adapted in this respect to the enormous traffic which passes over the river at this point, and its design, proportions, and entire character show a very marked advance upon those of the little bridge which it has replaced. The length of the bridge is 314 ft., the distance being covered by five spans. The width is 99 ft. between the parapets, 70 ft. of which is appropriated as a carriage way, and the remaining 29 ft. occupied by two footways, each 14 ft. 6 in. in width. The abutments are of bluestone, and the cornices and parapets of Stawell stone, which gives a highly finished appearance to the structure. The four piers consist each of eight cast iron cylindrical columns 6 ft. in diameter at the base. The cost was about £42,000.—*Australasian.*



THE QUEEN'S BRIDGE, MELBOURNE, VICTORIA, AUSTRALIA.

THE BRITANNIC—A REMARKABLE SHIP.

WE have on previous occasions drawn attention to the singular performances of many of the White Star Company's vessels. We say "singular" because the results attained are absolutely without parallel in the history of steam shipping. We could mention many fine ocean steamers belonging to the various companies which still do good work after some ten or fifteen years' service, but it is always the case that such vessels are relegated to the less important routes owing to their inability to maintain the requisite speed. In fact, taking the average experience with ocean steamers, it is found that in ten or twelve years' time they become obsolete, and it is then usually a question of re-engining and reboilering them, or selling them out of the fleet. Looked at, then, in the light of the average steamship capability, the record of some of the earlier White Star Company's vessels is simply marvelous, and, as we say, altogether without precedent.

We have before us the log of the White Star mail steamer Britannic, which arrived in the Mersey on Thursday evening, 4th September, from New York. She left New York at 9.35 p. m. (Greenwich mean time) on Wednesday, August 27, and arrived at Queenstown at 4.30 a. m. on Thursday, the 4th September, thus completing her 318th transatlantic passage in 7 days, 6 hours, 55 minutes, the fastest time she has yet made. The following is her log:

August	28	292	knots.
"	29	372	"
"	30	377	"
"	31	370	"
Sept.	1	376	"
"	2	377	"
"	3	387	"
—	—	261	" to Queenstown.
Total		2,812	knots,

or an average speed of 16·08 knots per hour. Fine weather prevailed during the passage. The Britannic's previous best performance was in March, 1888, when she crossed from Sandy Hook to Queenstown in 7 days, 9 hours, 30 minutes, which was regarded as sufficiently remarkable. But when it is remembered that this high speed, averaging over 16 knots per hour throughout, or nearly 19 statute miles, is obtained in a ship over 16 years old, with her original compound engines and boilers, on a small coal consumption, and with her large carrying capacity, it will be seen that the Britannic has been so constructed as to give results unattainable with the fastest ships of the present day, and actually increases in speed as she grows older, reversing the usual experience. It is worthy of mention that in ten voyages performed in 1888 the Britannic averaged 7 days, 15 hours, 57 minutes, while her sister ship, the Germanic, during 1889 made thirteen voyages averaging 7 days, 15 hours, 21 minutes, showing a wonderful uniformity in the speed of these twin vessels.

The Britannic and Germanic were built in 1874, by Messrs. Harland & Wolff, Belfast, and engined by Messrs. Maudslay, Sons & Field, London, the engines being a remarkably fine set of tandem compounds. The question may be asked to what do we attribute the magnificent performances of these vessels? We can only say that, in our opinion, a very great deal is to be credited to the shape of the hull. When any of our great liners are in dry dock, we make it a point to inspect them and compare the different lines. Any one who has done this, and compared the Britannic with other crack boats, cannot have failed to notice very great differences. The extreme fineness of entrance, the absence of forefoot, the long and full midship section, and the graceful run aft are features of these boats more pronounced than in most others. Again, a glance at the proportions of these boats and the results achieved prove the soundness of Scott-Russell's theory, that to obtain speed we must have great relative length. These points in the design of the hull have been carefully and judiciously considered by the talented designer of the White Star boats, Sir E. Harland, with the result that they are among the most economical as regards coal consumption of any vessels on the Atlantic. Of course, we can put, as it is sometimes done, unlimited power into a vessel and drive her.

This is, however, not scientific, and therefore not commercially successful. In the machinery of these vessels there is nothing very special except that at the date of its construction it represented the best marine practice.

Those who believe in "good iron" for ships and engines can certainly point to the Germanic and Britannic as an instance in point. Another very important factor has been the splendid workmanship put into these vessels, and another equally important

factor is that the owners have a name for keeping their vessels in the highest state of efficiency, no expense being spared to this end. Lastly, Messrs. Ismay, Imrie & Co. intrust their splendid vessels only to the very best men, as captains, engineers, and officers, that they can procure. Nothing except faithful service rendered, work honestly and carefully performed, could achieve these astonishing results. The company pay the highest wages, and so obtain the best service. The Britannic is commanded by Captain Henry Davison, R.N.R., who served his apprenticeship with Messrs. Ismay, Imrie & Co., has continued throughout in their employ in sail and steam, and was the captain of one of the White Star steamers in the Pacific trade for several years before obtaining his command in the Atlantic service. The chief engineer of the Britannic, Mr. Kitchen, has also a very creditable record. Before being promoted to the Britannic in August, 1888, Mr. Kitchen was for 16 years in charge of the Adriatic's engines, and during that time made 154 round voyages between Liverpool and New York, nearly a million nautical miles, without having any disablement in his engine room. It gives us peculiar pleasure to place the above facts on record. Not only from the technical point of view, but also from a higher standpoint, the performances of the Britannic reflect a luster on all concerned.—*Liverpool Journal of Commerce.*

RAILWAYS IN SYRIA.

REPORT TO THE STATE DEPARTMENT BY CONSUL BISSINGER, OF BEIRUT.

REVERTING to a previous report on railways in Syria (January 15, 1890), an imperial irade granting a concession for a railroad connecting Acca with Damascus was finally promulgated on the 13th of May last by his imperial majesty the Sultan sanctioning the conventions entered into between the imperial government and the grantee.

According to the plan submitted, and in accordance with the first application presented, Haifa, a small seaport at the foot of Mount Carmel, was to be the starting point. When the scheme, however, was minutely examined by the high military commission sitting at Yildiz Palace, in Constantinople, the head of the line was transferred to Acca, as offering, from a strategic point of view, more advantages to the government.

In fact, Acca is a well fortified military town of Syria, which was vainly besieged in 1799. Its population amounts to nearly 10,000 souls.

The concessionary is authorized to build the necessary jetties and landing places at both Acca and Haifa to enable vessels to come alongside the wharf, and to facilitate the loading and unloading of merchandise.

The grantee is bound to present the final corrected plans for the approval of the ministry of public works six months after the promulgation of the imperial firman, and the construction is to be completed two years after the approval of the plans. The future success of this undertaking seems to be assured. The line will traverse very fertile districts inhabited by a considerable population, composed of farmers and others who, for the most part, are well off in life. (See accompanying map.)

Acca (the Ptolemais of the ancients) was reputed for the abundance of its products; it served as a granary to the neighboring countries, which stored the surplus of their harvests therein to provide for needy days.

A line running for some distance along the littoral, and whose extremities rest on two seaports (Acca and Haifa), may, by this fact itself, expect to have a large traffic. It will have, moreover, the great advantage of monopolizing the exchange of commodities on the main line between the two principal towns (Acca and Damascus) and the terminal points of the branch lines between Banias and the Hauran.

The main line will run from Acca, on the Mediterranean, to Mejdel, and proceed thence in a northeasterly direction to Lake Tiberias, along which it will pass to a point where the river Jordan pours its waters into it. From there the line will follow the western bank of the Jordan to Jisr (bridge) Banat Yacoob, crossing it to its eastern bank. It will then continue almost due north along the course of the Jordan and the eastern bank of Lake Hooleh to below the village of Banias; thence in a northeasterly direction to its projected terminus, Damascus.

The above line will be 185 kilometers (about 115⅝ miles) in length. Another line, 40 kilometers (25 miles) long, starting from Banias, will proceed in a southeasterly direction to Nawa in the Hauran. These lines are obligatory.

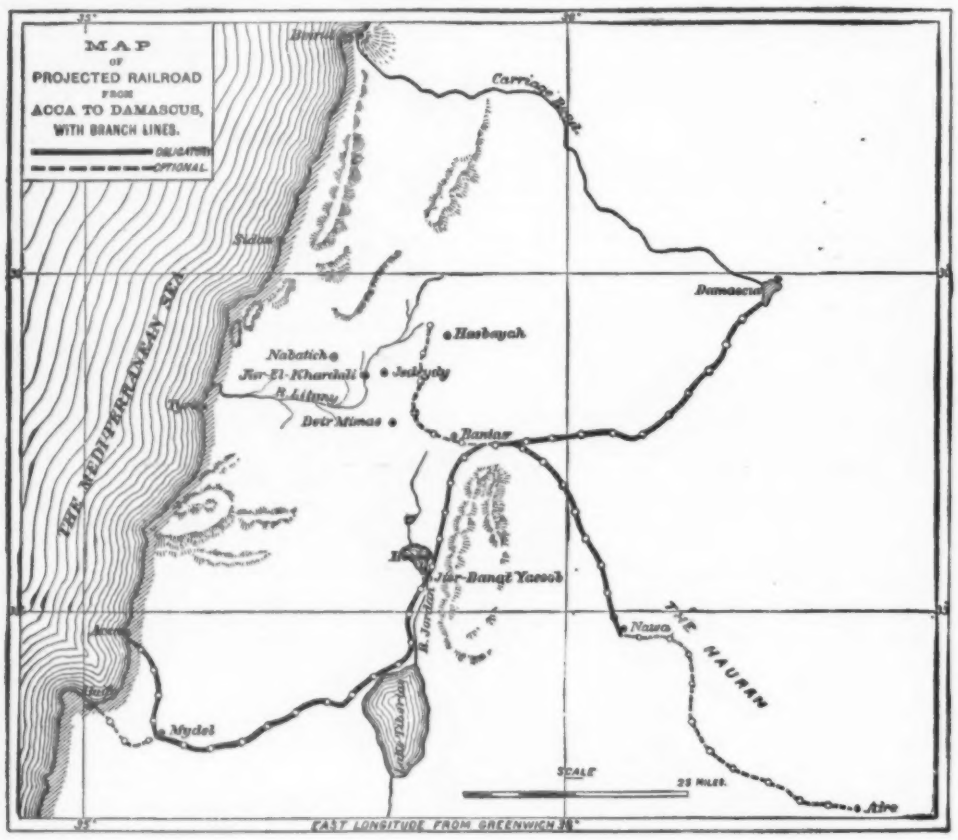
From Nawa a line about 55 kilometers (34⅛ miles) in length will be prolonged as far as Airé, in the Hauran; this is optional. Another optional line, 30 kilometers (18¾ miles) long, will begin in the neighborhood of Banias and end at Hasbaya. A third line, also optional, 15 kilometers (about 9⅜ miles) in length, is to be built between Acca and Haifa, having its starting point at Mejdel, 20 kilometers (12½ miles) distant from Acca.

Another important route, for which, however, no concession has as yet been obtained, may be built between Banias and Beirut. The line, it is presumed, would start from below Banias, run almost due west to Convent Deir Mimas, from which place it would probably proceed to Jisr el Khardali, southwest of Djedeydy; thence to Nabatieh northwest. From Nabatieh the line would follow a northwesterly direction to above Sidon, then along the littoral to Beirut.

A notable capitalist, of London, who is supposed to represent a powerful English party, is said to be at the head of these enterprises. The capital of the society is to be about 1,300,000 Turkish pounds, equal to $5,720,000.

ERHARD BISSINGER, Consul.

United States Consulate, Beirut, June 15, 1890.



ON THE ELECTRO-DEPOSITION OF PLATINUM.*

By WILLIAM H. WAHL.

THE permanence and unalterability of the metal platinum—properties which make it of such inestimable value to the chemist—have likewise suggested its application as a protective covering upon the surfaces of other metals, and, even in the early days of the art of electro-deposition, efforts to obtain a satisfactory coating of this metal were made. The failure with which these early experiments were attended served rather to stimulate than to deter subsequent investigators, and the problem has received the attention of a number of the most noted experts in the art. The results that have been accomplished cannot be said to have been entirely satisfactory—a statement which, I believe, will be fully sustained by the fact that electro-plating with platinum, on the commercial scale, is practiced only to a very limited extent. When the wide field of application for platinum plating is considered—and I need only name philosophical, engineering, surgical, dental and electrical apparatus and instruments, fire arms, watch cases, and jewelry, to say nothing of the host of miscellaneous articles of utility and ornament to which the metal could be advantageously applied—the conclusion is irresistible that the processes thus far proposed for the purpose do not fully meet the requirements of practical service.

Thus far, of all the methods that have been proposed for electro-plating with platinum, three only appear to have sufficient merit to deserve special notice; these are:

1. Roseleur-Lanaux method, based on the electrolysis of a solution of the double phosphate of sodium and platinum.

2. The process of the Bright Plating Company (of London), a modification of that of Roseleur, involving the introduction into the bath of certain substances, such as sodium chloride and borax, to insure a bright deposit of the metal; and

3. Boettger's method, founded on the electrolysis of a solution of the double chloride of ammonium and platinum in sodium citrate.

Each of these baths will yield satisfactory results for a time. But, as I shall endeavor to show, the peculiar difficulties met with in the practice of platinum plating render it impossible to maintain the chemical integrity of these electrolytes, and in consequence thereof they soon become inefficient or inoperative by reason of contamination with the secondary products formed therein.

I will endeavor in what follows to give the true explanation of the difficulties above referred to, and to indicate what, from a careful study of the subject, fortified by the results of numerous experiments, I conceive to be the only feasible method of overcoming them.

The first difficulty encountered is that of obtaining a bright, reguline and adherent deposit of the metal, in which form only it will answer the demands of practice. There is no difficulty in effecting the separation of the metal from solutions of almost any of its compounds.

Zinc, iron and tin reduce it promptly by simple immersion, and this very facility of reduction is one of the reasons why, even by the method of electrolysis, the desired object is frequently accomplished only in an imperfect manner. For the electro-plater is obliged to meet and overcome its obstinate disposition to separate from many of its compounds in the condition of platinum black, lacking coherence and adherence, and therefore entirely unsuited for his purpose.

Another and no less serious difficulty arises from the insolubility of plates or sheets of this metal as anodes, when solutions containing platinum salts are submitted to electrolysis. In electro-plating with copper, silver, gold and nickel but little difficulty is encountered in practice on this account, since anodes of these metals are freely soluble in many solutions capable of depositing them when they are submitted to electrolysis, and the rate at which these anodes are respectively dissolved approximates so nearly to that at which the metals are deposited upon the objects at the cathode, that the metallic strength of the electrolyte is maintained substantially uniform, and electro-plating solutions of these metals may be operated for a long time without requiring additions of metallic salts. The electro-deposition of the metals whose anodes are thus tractable is carried on industrially with success.

It results from this want of solubility of the anode that the metallic strength of the electrolyte employed is continuously being weakened, while the deposition of the metal is going on and the conductivity of the bath is being continually modified thereby. The character of the depositing metal also is injuriously influenced by these constant alterations of condition in the bath. And, as the rate of deposition becomes slower and slower by reason of the gradual impoverishment of the metallic strength of the solution, it will be necessary to restore it by fresh additions of metallic salt. The practice in all the processes of electro-plating with platinum employed up to the present time, save that of Boettger, is to use for this purpose the tetra-chloride of platinum. With this single exception, all the solutions for the electro-deposition of platinum thus far made known, so far as I am aware, are made by treating the chloride with compounds of the alkalies, soda, potassa or ammonia. Of these, the phosphates and oxalates of soda or potassa are in greatest favor, and a number of formulæ for preparing platinum plating baths with their aid have been described. The resulting substance is commonly a double salt, such, for example, as the double phosphate of sodium and platinum, the double oxalate of potassium and platinum, etc., contaminated, however, in each case by the chloride of the alkali employed, which is formed from the decomposition of the platinic chloride. As often as it is found necessary to strengthen the bath, fresh additions are made of platinic chloride, which, by chemical interaction with the constituents of the bath, aided by the process of electrolysis, yields more alkaline chloride, and it follows that the bath, by reason of becoming surcharged with this foreign substance, and with other secondary products of electrolytic decomposition, ceases to yield bright, reguline platinum upon the articles to be plated therewith and must be discarded. It then becomes necessary to regain the platinum contained in the discarded bath, by one or another of several processes of reduction known to chemists. The platinum thus regained may be converted into chloride and utilized in the preparation of a fresh bath, with which the same series of operations will be repeated. Boettger purposes to maintain his bath by fresh additions of his original solutions, but it must be apparent that the continued electrolysis of such a solution as he employs must be attended with the constant accumulation therein of alkaline chlorides from the same causes as those specified above. This rapid deterioration of the baths therefore involves their frequent renewal at the expense of time and labor, so that, in spite of the fact that there is a wide field for its application, it is principally for this reason that the art of electro-plating with platinum on the commercial scale has thus far been practiced only to a very limited extent.

It occurred to me that it might be practicable to overcome the principal difficulty here set forth. Knowing the influence of extent of surface in promoting the solubility of substances, it appeared to me at least probable that if the platinum were exhibited at the anode in the form of platinum black, or sponge, exposing thus an enormously greater number of points of attack to the electro-negative element or acid radical there set free, the result might be the solution of the platinum, and the problem of maintaining the metallic strength of the electrolyte would thus be solved.

The correctness of this conjecture was verified by experiment. For this purpose a plate of porous battery carbon, previously treated with boiling hydrochloric and nitric acids, was saturated repeatedly with a solution of platinic chloride and dried. It was then intro-

* Read at the stated meeting of the chemical section of the Franklin Institute, May 20, 1890.

duced into a graphite crucible, finely divided carbon was packed about it, and the crucible and contents heated for about half an hour to bright redness. The carbon plate then contained within its pores platinum in a state of eminently fine division. Treatment with water and with hydrochloric acid at boiling temperature failed to leach out any platinum salt, showing that the previous treatment had sufficed to reduce all the platinum salt to the metallic state. The carbon plate was then suspended as the anode in moderately diluted hydrochloric acid, a platinum plate serving as the cathode. The acid bath was gently heated and a current of moderate strength was allowed to flow through it. There was a liberal evolution of hydrogen from the cathode, but little perceptible evolution from the anode. The acid solution gradually became colored from the formation of platinic chloride, and after some time the bright surface of the cathode began to blacken and ultimately became covered with a thick coating of platinum black. It was thus demonstrated that an anode of platinum in a fine state of division is readily soluble in an electrolyte which yields chlorine at the anode when the same is electrolyzed. This observation, so far as I am aware, is new. It proved, however, to have no practical value, since the solution of the anode demanded the presence of a large proportion of free acid in the plating bath and the use of currents of such strength as to produce invariably the deposition on the surfaces to be plated of black and non-adherent metal. Furthermore, it was found, as was to have been anticipated, that the physical condition of the anode exerted no influence whatever in the electrolysis of baths formed of the oxy-salts of platinum, from which the best results in electro-plating are obtained—since, in electrolyzing such compounds, the acid radical separated upon the surface of the platinum black failed to exert any perceptible solvent action.

It was, therefore, necessary to devise some other plan for overcoming the difficulties herein described, and, after making a number of fruitless experiments, I was so fortunate as to find a plan which appears to offer a solution of the troublesome problem of electro-plating with the group of metals whose anodes are insoluble, in a more satisfactory manner than any other that has hitherto been suggested.

The plan here referred to consists in employing platinum hydroxide for the purpose of maintaining the metallic strength of the plating bath. For this purpose, the hydroxide, which is readily soluble in alkalies and in many of the acids, may be introduced into the plating bath from time to time and dissolved therein by stirring, or it may be permitted to remain in the bath in excess, the undissolved portion remaining at the bottom of the containing vessel, or it may be suspended in a canvas bag adjacent to or surrounding the anode of carbon, according as the nature of the electrolyte may indicate one or the other method to be the preferable one. As the solutions which yield the best results in plating are those of the oxygen salts, I have found it advantageous also to prepare these directly from the hydroxide. This method, I have found, is capable of yielding a number of electrolytic baths of platinum that will maintain their metallic strength approximately unimpaired during electrolysis, and without the objectionable features of introducing into them substances that will cause them to deteriorate by the accumulation therein of injurious secondary products of decomposition, as is the case where such baths are maintained by additions of platinic chloride or alkaline chloroplatinates, as has hitherto been the invariable practice. Referring now specifically to the properties that render the platinic hydrate useful for the purposes above indicated, the following points appear to be deserving of mention.

It is readily soluble in aqueous solutions of the alkaline hydrates, and in a number of acids, mineral and vegetable. In the treatment of the platinic hydrate with aqueous solutions of the alkaline hydrates, the former plays the part of a weak acid, forming compounds known as platinates, which are very soluble, and from which the platinum is not precipitated on the addition of an excess of alkali. A weak aqueous solution of sodic or potassic hydrate (but especially the last named) will dissolve a large quantity of platinic hydrate, at the ordinary temperature, though solution takes place more freely when heat is applied. These solutions have the advantageous features of being freely conductive of electricity, and of yielding bright, reguline, and adherent electro-deposits of platinum on metallic surfaces previously prepared to accept the same. Furthermore, with a current of moderate strength, the platinic hydrate only is affected, as is shown by the pronounced evolution of oxygen at the anode and by the total absence of gas at the cathode. Also, it is manifest from the free solubility of platinic hydrate in alkaline hydrate, even in the cold, that if free platinic hydrate be present in a bath of alkaline platinate, the alkali set free in the process of electrolysis will combine with this platinic hydrate to form fresh platinate. For this purpose, it will be necessary either to have present in the bath at all times a small excess of platinic hydrate which may remain upon the bottom of the containing vessel, without interference with the plating, and which may be replenished from time to time, or to introduce, at the end of the day's work, a quantity of the platinic hydrate sufficient to restore the metallic strength of the bath to normal, assisting the solution of the metallic hydrate by stirring, and if necessary by the application of gentle heat. As I have found that the platinate solutions act best when they contain a considerable excess of free alkaline hydrate, being more conductive of the current and yielding the platinum more freely and in the best condition, the addition of the proper quantity of platinic hydrate at the close of the day's work in the case of a bath of considerable volume, or the addition of small quantities at intervals, in the case of a small bath, will be found to answer the desired purpose of maintaining the metallic strength of the bath approximately normal for an indefinite period. In a bath where considerable free alkali is present, the platinic hydrate added as just indicated dissolves very freely even in the cold. The important fact is to be noticed that the alkaline platinate solutions may be maintained and operated for a long time in the manner described, since no deleterious secondary products are formed by electrolysis to vitiate and render them inoperative, as will speedily be the case where the platinic chloride is used for this purpose.

The mineral acids (hydrochloric, nitric, sulphuric, and phosphoric acids) dissolved the hydroxide freely, as likewise do certain of the vegetable acids, notably oxalic acid, and form with corresponding salts of the alkalies double salts, many of which are soluble in water. Of the salts thus capable of being formed, however, so far as I have been able to determine by experiment, only a limited number appear to be adapted to yield a deposit of bright, reguline and adherent platinum. The halogen compounds may obviously be prepared more conveniently by the direct solution of the metal in *aqua-regia* than by the method I have described, but as I have found the oxygen compounds of platinum to yield much more satisfactory results, I therefore exclude them from consideration.

Of the salts that may be formed from platinic hydrate by solution in acids (and in part by suitable combination with the corresponding alkaline compounds to form double salts), three only may be named as sufficiently useful to yield practically valuable results in plating. These are the phosphates, oxalates and acetates, of which also it is practicable to form double salts with the alkalies, soda, potassa and ammonia, which yield bright, reguline and adherent plating.

Oxalic acid, so far as I have been able to determine, of all the oxygen acids, is the best solvent of platinic hydrate, dissolving it even in the cold, but with great energy when aided by heat, and forming platinous oxalate, with evolution of carbonic anhydride. From this brownish black or deep blue solution (according to concentration), brilliant reddish brown scales of the salt separate abundantly and readily from the hot saturated solution. A saturated aqueous solution of the simple oxalate prepared from the hydrate as above described will yield bright, reguline, adherent platinum when electrolyzed with a comparatively weak current, with evolution of carbonic anhydride at the anode. With a stronger current hydrogen also appears at the cathode. This bath may be maintained indefinitely at normal metallic strength by observing the precaution to add oxalic acid and platinic hydrate in small quantities from time to time; or by keeping constantly at the bottom of the bath some platinic hydrate, and adding oxalic acid in crystals or powder from time to time as may be required to keep the bath saturated; or, what is much to be preferred, making a supply of platinous oxalate from platinic hydrate in the manner previously described and keeping an excess of this present in the bath at all times. This bath has the same advantages as are possessed by the above described alkaline platinate baths, of being capable of indefinite maintenance at normal metallic strength and of introducing no substances that will cause its deterioration by the formation of secondary decomposition products.

Phosphoric acid also is a solvent of platinic hydrate. A dilute aqueous solution of this acid will dissolve a small quantity of the metallic hydrate in the cold, and a much larger quantity when aided by heat. With increasing concentration, the solvent power of this acid for platinic hydrate is correspondingly increased. The resulting solution of phosphate of platinum, according to the degree of concentration, will be wine-yellow to cherry-red in color, and with a comparatively weak current will yield bright, reguline and adherent platinum on metallic surfaces properly prepared to accept the same. The electrolysis of this compound also does not involve the formation of deleterious secondary products, the result of the operation being the separation of the metal at the cathode, and of the acid radical at the anode—and of the elements of water which are evolved as gases respectively from anode and cathode. In the operation of the bath, therefore, it will become more and more acid as the metal is withdrawn by the accumulation therein of the phosphoric acid set free at the anode. The maintenance of the metallic strength of the bath, therefore, may be effected as in the foregoing cases by having present at all times a small quantity of platinic hydrate or by the addition at the end of each day's work of the quantity of the metallic hydrate which will be required to restore the amount of metal withdrawn. This bath must be worked very acid, and the solution of the platinic hydrate to maintain the strength of the bath must be facilitated by heating, as the solvent power of phosphoric acid for platinic hydrate is much inferior to that of oxalic acid. The double phosphates of platinum with certain of the alkalies may be formed, which will be capable of yielding a deposit of bright, reguline and adherent metal, and of being maintained approximately at normal metallic strength in the same manner as I have set forth above. The best results I have obtained with the ammonio-platinic phosphate, prepared by adding to the solution of platinic hydrate in phosphoric acid sufficient aqua ammoniæ to cause the same to give an alkaline reaction, which point will be indicated by the formation of a grayish precipitate that will not disappear on stirring; then restoring the acidity of the solution by adding free phosphoric acid in excess, upon which the precipitate readily dissolves. The resulting solution is yellowish or brownish, and yields superb plating, though, on account of the greater difficulty of maintaining its metallic strength by the solution of the hydroxide, it is not so well adapted as the oxalate for the work of electro-deposition on the large scale. The sodio-platinic phosphate, formed in a manner precisely analogous to the ammonia compound just described, will also yield bright, reguline and adherent plating; but I have observed that the soda salt is less freely soluble than the corresponding ammonia compound, and consequently more difficult than the latter to maintain of normal metallic strength.

Platinic hydrate is only very sparingly soluble in strong acetic acid, and it is impracticable to facilitate the solution by boiling, since by persisting in this for a very short time, the hydrate is decomposed and black platinic oxide formed which is quite insoluble in this menstruum. I have found, however, that an alkaline acetate bath may be prepared by the addition to the alkaline platinates above described of as much acetic acid as may be introduced without causing the formation of a permanent precipitate. But although the appearance and quality of the plating obtained with this bath leave nothing to be desired, the bath does not meet the requirements in respect of indefinite maintenance in normal metallic strength and uniform composition. This difficulty, however, as I have observed, becomes less and less pronounced as the bath is made more strongly alkaline, when it approximates more and more closely to the alkaline platinates, for it is obvious that in the presence of a large amount of free alkali, this would unite with the acetic acid to form a simple acetate. The resulting solution would no longer contain sodio- (potassio-) platinic acetate, but sodic (potassic) acetate, sodic (potassic) platinate, and free alkali. Nevertheless, the presence of acetic acid in such alkaline bath appears favorably to influence the quality of the plating yielded, giving the deposited metal a whiteness approaching that of silver, and since, furthermore, acetic acid yields only the elements of water and volatile compounds, when electrolyzed, and therefore does not contaminate the electrolytic bath by forming deleterious secondary products, I find its judicious addition to the above described alkaline platinate baths to present some advantages.

The foregoing comprise the compounds that I have found to yield the most satisfactory results in platinum plating, and I will not tax your patience at this time by an enumeration of the results, either partially successful or wholly unsuccessful, that I have obtained with a number of differently constituted compounds of this metal.

I append directions for the preparation of the several electrolytic baths above described, and indicate what I have found to be the most favorable conditions for working them.

In conclusion, I desire to make known the fact, which was brought to my knowledge only within the past week, that my friend, Prof. Wm. L. Dudley, of Vanderbilt University, Nashville, Tenn., has independently worked out the problem of electro-plating with iridium in a manner precisely analogous to that which I have herein described with platinum. Prof. Dudley has made no publication of his research, but in a letter informs me that he employed, as long ago as 1886, the following procedure, which I quote: "A bath of the metal may be composed of either the chloride ($IrCl_4$), the double chloride of iridium and sodium, a double sulphate of iridium-ammonium. The latter was preferred. The bath was kept saturated with metal by suspending canvas bags in the solution (either near to or around the anodes) containing the hydroxide of iridium."

Directions for Preparing the Electro-plating Baths.—For the alkaline platinate bath, the following directions may suffice:

Platinic hydrate	2 oz.
Caustic potassa (or soda)	8 oz.
Distilled water	1 gallon.

Dissolve one-half of the caustic potassa in a quart of distilled water; add to this the platinic hydrate in small quantity at a time, facilitating solution by stirring with a glass rod. When solution is effected, stir in the other half of alkali, dissolved in a quart of water; then dilute with enough distilled water to form one gallon of solution. To hasten solution, the caustic alkali may be gently heated, but this is not necessary, as the platinic hydrate dissolves very freely. This solution should be worked with a current of about two volts and will yield metal of an almost silvery whiteness upon polished surfaces of copper and brass, and quite freely. There should be slight, if any, perceptible evolution of hydrogen at the cathode, but a liberal evolution of oxygen at the anode. I have observed that the addition of a small proportion of acetic acid to this bath improves its operation where a heavy deposit is desired. The anode may be of platinum or carbon, and owing to the readiness with which the metal is deposited, an excess of anode surface is to be avoided. Articles of steel, nickel, tin, zinc, or German silver, will be coated with black and more or less non-adherent platinum, but by giving objects of these metals a preliminary thin electro-deposit of copper in the hot cyanide bath, they may be electro-platinized in the alkaline platinate bath equally as well as copper. The bath may be worked hot or cold, but it is recommended to work it at a temperature not exceeding 100° F. It may be diluted to one-half the strength indicated in the formula and still yield excellent results. The surface of the objects should be highly polished by buffing or otherwise, prior to their introduction in the bath, if the resulting deposit is designed to be brilliant.

The deposition of platinum takes place promptly. In five minutes, a sufficiently heavy coating will be obtained for most purposes. The deposited metal is so soft, however, that it requires to be buffed very lightly. A heavier deposit will appear gray in color, but will accept the characteristic luster of platinum beneath the burnisher.

The oxalate solution is prepared by dissolving one ounce of platinic hydrate in four ounces of oxalic acid and diluting the solution to the volume of one gallon with distilled water. The solution should be kept acidified by the occasional addition of some oxalic acid. The simplest plan of using this bath, and which requires no attention to proportions, is simply to work with a saturated solution of the oxalate, keeping an undissolved excess always present at the bottom of the vessel. An addition of a small quantity of oxalic acid now and again will be found advantageous. The double salts of oxalic acid with platinum and the alkalies may be formed by saturating the oxalate of the desired alkali with platinic hydrate and maintaining the bath in normal metallic strength by the presence of an undissolved residuum of platinous oxalate.

The double oxalates are not so soluble in water as the simple salt. The oxalate baths, both of single and double salts, may be worked cold or hot (though not to exceed 150° F.), with a current of comparatively low pressure. The metal will deposit bright, reguline and adherent on copper and brass. Other metallic objects must receive a preliminary coppering as above. The deposited metal is dense, with a steely appearance, and can be obtained of any desired thickness.

The deposit obtained in the oxalate baths is sensibly harder than that from the alkaline platinate bath, and will bear buffing tolerably well.

The phosphate bath may be prepared by the following formula:

Phosphoric acid, sirupy (sp. gr. 1·7)	8 oz.
Platinic hydrate	1–1½ oz.
Distilled water	1 gallon.

The acid should be moderately diluted with distilled water, and the solution of the hydrate effected at the boiling temperature. Water should be added cautiously from time to time, to supply that lost by evaporation. When solution has taken place, the same

should be diluted with sufficient water to make the volume one gallon. The solution may be worked cold or warm to 100° F., and with a current much stronger than that required for the platinates and oxalates. The ammonio-(and sodio-) platinic phosphates may be formed from the simple phosphate by carefully neutralizing the solution of the phosphate with ammonia (or soda); then adding an excess of phosphoric acid, or enough to dissolve the precipitate formed and an additional quantity to insure a moderate amount of free phosphoric acid in the bath. The phosphate baths will be maintained of normal strength by additions of platinic hydrate, the solutions of which will have to be assisted by heating the bath, preferably at the close of each day's work. The metal yielded by the electrolysis of these phosphate solutions is brilliant and adherent. It has the same steely appearance as that exhibited by the oxalate solutions, but to a less pronounced degree. The physical properties of the deposited metal are in other respects like those described in connection with that obtained from the oxalate baths.

THE DARBY PROCESS OF RECARBURIZATION.*

IN experiments for the production of steel the chief point in the solution of the problem is always the introduction into or the removal from the iron of a determinate quantity of carbon.

As is widely known, in order to produce in the converter, by means of Sir Henry Bessemer's great invention, steel of a wished for percentage of carbon, two methods present themselves. By the one the process is stopped when the bath possesses the desired contents of carbon; by the other the bath is completely decarburized, and then the wished for carbon added in the form of spiegel, ferro-manganese, etc. In Germany the latter method only came into use and was retained when the Thomas-Gilchrist process for the production of steel, low in phosphorus, from highly phosphoric iron in the basic converter came successfully into use. The more so as from the nature of the process, before

* A paper read at the international meeting of the American Institute of Mining Engineers at Pittsburg, October 4, 1890, by Mr. A. Thielen, Managing Director of the Phœnix Steel Works, at Ruhrort, Rhenish Prussia.—*Reported in Engineering and Mining Journal.*

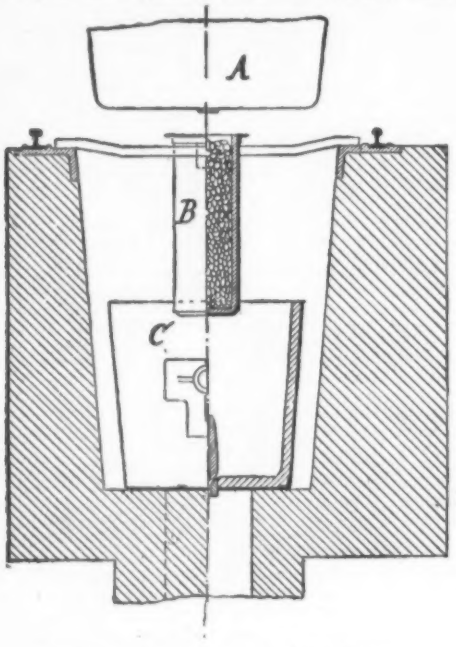


FIG. 1.—DARBY'S CARBON FILTER.

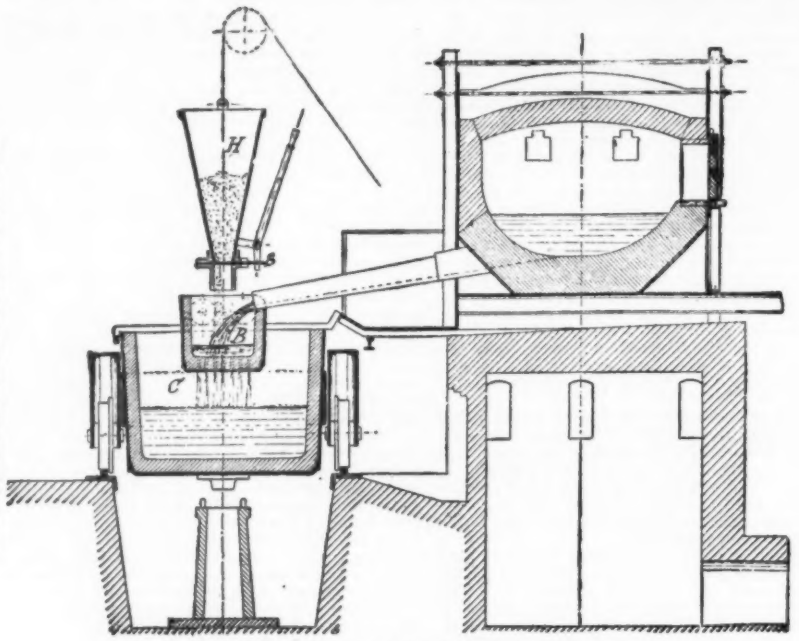


FIG. 2.—DARBY'S RECARBURIZING PROCESS.

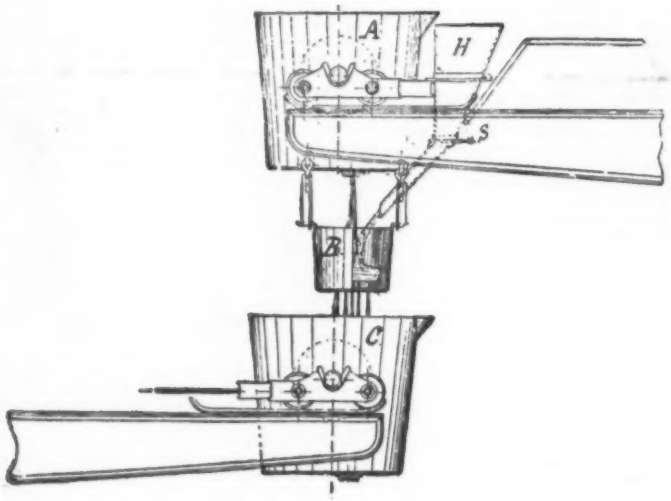


FIG. 3.

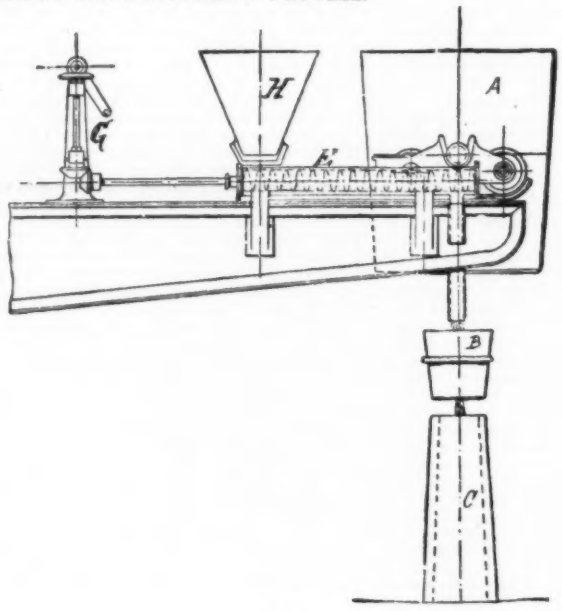


FIG. 4.

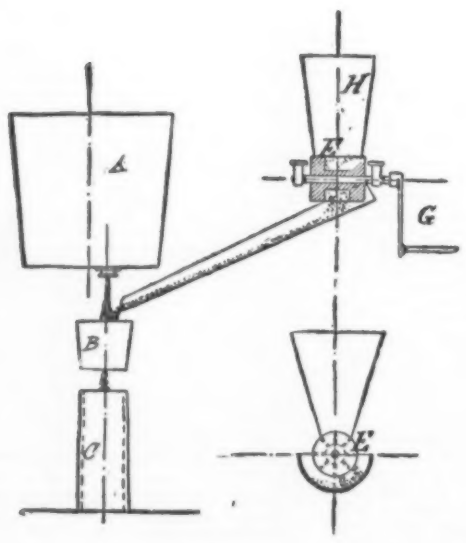


FIG. 5.

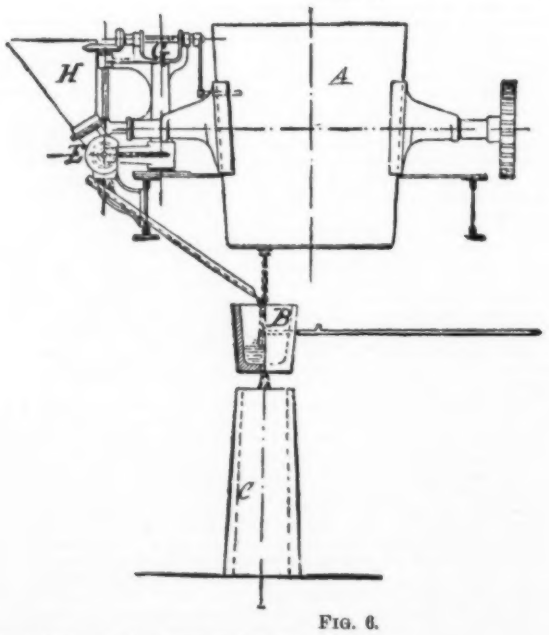


FIG. 6.

DARBY'S RECARBURIZING APPARATUS—LATEST IMPROVEMENTS.

dephosphorization takes place, complete decarburization is necessary; but while, by the old acid process, the carburization readily takes place by the simple addition of spiegeleisen, etc., the new process brought with it difficulties, not easy to be overcome, inasmuch as the oxides which are always present in the basic process to a larger or smaller extent, and also the phosphoric acid of the slag, take part in the reaction. Even if one succeeded in removing part of the oxide by pouring off the slag and regulating the amount left dissolved in the bath by so perfecting the process that there would be approximately an equal amount remaining in each charge, and even if the danger of rephosphorization were diminished by as complete a removal of the slag as possible and by suitable slag additions made to the still remaining slag, still the production of low phosphorus steel high in carbon could not be accomplished so readily as not to make the introduction of another simple method of carburizing well worth wishing for. The circumstances are similar as regards the basic and acid open hearth processes.

It can readily be understood, therefore, why, after the introduction of the method of making steel in basic lined vessels, proposals which had been formerly made for the introduction of carbon other than by the indirect way, by means of spiegel, etc., but which had hitherto remained without results, should be brought forward again from various quarters. All these processes were based on the known fact of the great affinity between carbon and iron at high heats. It was sought to reduce and carburize the bath of steel by the introduction of carbureted gases, by the addition of tar, petroleum, etc., as well as many mixtures of these substances with solid bodies such as burnt dolomite. However, the result of all these experiments did not lead to the permanent introduction of any of them in practical work, until Mr. John Henry Darby, the Managing Director of the Brymbo Steel Works, succeeded in finding a solution of the problem.

Having attentively noticed an increase of carbon which took place in two pieces which had been treated in the coal fire for welding, he brought fluid steel into intimate contact with solid carbon, the result being a rapid absorption of the carbon by the steel. Supported by this experiment, he founded on it his patented process by which fluid steel can be carburized by filtration through pieces of carbon, preferably in the form of graphite or charcoal, etc. He employed for this purpose the apparatus shown in Fig. 1.

This consists of a sheet iron cylinder *B*, open at the top and closed at the bottom by a plate pierced with numerous holes, the whole being lined with refractory material. It is filled with carbonaceous material and inserted either between the two steel ladles *A* and *C* or between the Siemens furnace and the steel ladle. The fluid steel takes its way through the interstices of the pieces of carbon, and is thereby brought, by absorption of the carbon, to the wished for percentage of carbon.

Further experiments showed that the absorption of the carbon was so rapid as to make the long time of contact, which the above described filtration gave, unnecessary. Mr. Darby, therefore, constructed the apparatus figured in Fig. 2.

In this the cylindrical filter is replaced by the vessel *B*, which is conveniently supported between the open hearth furnace and the steel ladle, or between two other steel ladles. It is, as the filter, lined with refractory material, and is furnished with a perforated refractory bottom plate. Above this vessel is placed the receptacle *H*, containing the roughly broken carbonaceous material. This receptacle is closed by a slide valve *S*, by the opening of which the carbon is allowed to fall, slower or faster, as desired, into the vessel *K*, and there mixes with the fluid steel, which is thereby carburized and flows out through the holes in the bottom plate. As a rule, the carburization takes place during the first third of the charge. The remainder of the soft steel then mixes with the already carburized steel in the ladle to a homogeneous whole. The loss of carburizing material (graphite) by burning is about 15 per cent. to 20 per cent.; when coke is used for carburizing, the loss is greater.

All Mr. Darby's experiments referred to the carburizing of open hearth steel, and he succeeded by his process, in conjunction with the basic process, in producing from phosphoric raw material a very excellent product, which with any wished for percentage of carbon to upward of 0·9 per cent. contains only very small traces of other bodies, and consequently is distinguished from all hitherto known open hearth steel by its exceeding toughness. It has been worked up into chisels, knives, wire, etc., with the best results. And there was very great certainty in obtaining the right percentage of carbon, the percentage obtained varying from that wished for seldom more than 0·01 per cent. to 0·02 per cent. The rolling quality of the material, although only very small additions of ferro-manganese or ferro-silicon were made, was very good. The process was very soon exclusively employed at Brymbo, for the harder steels, but in order to introduce his system to the Bessemer process, Mr. Darby, in 1889, entered into an agreement with the Phœnix Company, of Laar, near Ruhrort on the Rhine. The experiments were arranged in the basic Bessemer works with the apparatus shown in Fig. 2, to which the arrangement represented in Fig. 3 was given. The carburizing vessel *B* was arranged between the two ladles *A* and *C*, standing one over the other, and the steel carburized while streaming from the first into the second ladle by the stream of carbonaceous material issuing from *H*, regulated by the valve handle *D*. It quickly appeared, however, that the bassic Bessemer steel, although readily carburized, yet thereby lost its rolling qualities to such an extent that the ingots fell to pieces in the rolls. On inquiring into the cause of this it was discovered to be due to the method of carrying out the process, viz., that for four minutes more than 60 fine streams of steel were oxidized, by means of the atmospheric oxygen. It was sought to overcome this drawback by replacing the 60 holes in the bottom of the vessel by one of a suitable diameter. A considerable improvement in the rolling quality of the ingots was thereby produced. But the rolling quality attained was not equal to that of the ordinary Thomas ingots, and the apparatus was on this account superseded by the arrangement shown in Fig. 4. The carburizing vessel was here replaced by the refractory lined funnel, *B*, open at the bottom, which was arranged between the casting ladle and the moulds. By an arrangement attached to the side of the casting crane it was impossible to introduce into the funnel *B* the ground carbonaceous material little by little in a well regulated stream. This arrangement consists of an accurately bored cylinder *E*, provided with a lathe-cut worm, the receptacle *H*, and the turning arrangement *G*. As is readily apparent, the amount of carbonaceous material forced out is proportional to the number of rotations which the endless screw makes, which can be accurately regulated. By the employment of this apparatus the carburizing is safely done in the wished for manner and good rolling ingots obtained. The ground coke appeared to be more quickly absorbed than the graphite, so that all the experiments were carried out with this material. It was found that with ingots weighing 1,400 kilos and measuring 16 inches square, the carbon was very equally distributed throughout. By some attention the frequently occurring increase of carbon in the top parts of ingots of this weight was successfully overcome by a lessened addition of carbon to the upper part. In order to test the equal distribution of the carbon, ingots were rolled down into 2 inch billets, and tests taken from the two ends and the middle of the same.

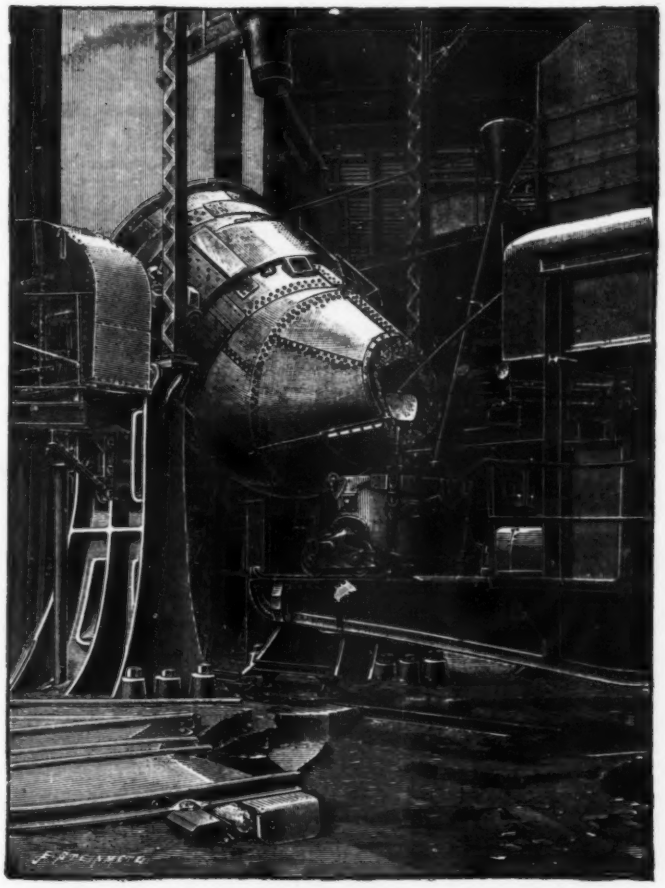


FIG. 7.—DARBY'S RECARBURIZING PROCESS.

Fig. 5 shows a second arrangement for carrying out this process. The carbonaceous material flows from the holder, H, into the fan wheel, E. By turning the wheel by means of the winch, G, the filled compartments empty themselves and allow the carbonaceous matter to flow in regulated quantity into the vessel, B.

Although this method of carrying out the process offered considerable advantages over the earlier way, yet it brought this disadvantage with it, that the accuracy and amount of the carburization were essentially dependent on the reliability of the workmen in charge of the rotation of the endless screw. To effect the rotation by mechanical means appeared impracticable, because it must continually be brought into accord with the speed of the stream of molten steel, which varied according to the temperature and condition of the stopper hole. The observation that the carbonaceous material, finely ground coke, is immediately absorbed at the first contact with the molten steel, led to an arrangement by which this latter drawback was obviated. By the arrangement shown in Fig. 6 the carbonaceous material could be added directly to the stream of molten steel flowing from the converter before it reached the ladle, C, while the slag could be retained in the converter until the carburization was complete, by means of a suitable plate, F, lined with refractory material or by a block of refractory material. The quantity of the carbonaceous material flowing out from the receiver, H, is, as before, regulated by means of the slide valve, P. In this way there were produced during the month of June at the said works 70 per cent. of the steel rail charges, also a number of charges for hard and welding Thomas steel, the whole of which gave satisfactory results. It may be remarked that with the carburizing process, in the Thomas process the same addition of ferro-manganese is required as for soft ingot charges or is necessary for the production of hard sorts of steel with spiegeleisen.

After a series of very successful results had been obtained in this simple way the process was employed also in the open hearth and ordinary Bessemer practice. As was to be expected, the results obtained were so favorable that now the employment of the carburizing vessel has been regularly adopted in these works.

Collecting now, in conclusion, the advantages which this carburizing process offers in each of the methods for the production of steel, we find :

1. In the basic Bessemer (Thomas) process, the carburizing takes place in the almost complete absence of the slag, rich in oxides and phosphoric acid; consequently it proceeds with certainty, it is accompanied by no important rephosphorization, and is practicable for any desired percentage, without simultaneously increasing the manganese. By the omission of the spiegeleisen a considerable economy is effected.

2. In the Bessemer process, the carburization takes place up to the highest grade of hardness with far greater safety than by the help of spiegel, and without the increase in manganese consequent upon the employment of the latter process. Here also a considerable economy is effected, due to the saving in spiegel. The trials were made among others in some American works.

3. In the open hearth process; for the acid and basic open hearth processes, the advantages offered are very nearly identical with those mentioned for the Bessemer and Thomas processes; the very considerable cost of the ferro-manganese and ferro-silicon, especially, is wholly or for the greater part avoided. The combination of the process with the basic open hearth process permits of the production of a steel which for many industrial purposes successfully compares with crucible steel. By this method also a material is produced which in the future will find very advantageous employment as the raw material in the crucible steel process.

For example: for the production in the basic converter of a rail steel of 50 kilogrammes per square millimeter tensile strength there is required for the production of a charge of from 9 to 9·5 tons output:

(a) By the employment of the ordinary process:

Spiegeleisen 10–12 per cent.....	600 kgs.
Ferro-manganese 60–65 per cent.....	80 "

(b) By the employment of carburizing process:

Spiegeleisen.....	nil.
Ferro-manganese 60–65 per cent.....	80 kgs.
Coke.....	60 "

For the acid process the calculation also shows itself in favor of the carburizing process.

If steel of similar hardness is to be produced in the basic open hearth furnace, there is required for a charge of 10 tons output:

(a) By the employment of the ordinary process:

Spiegeleisen 10–12 per cent.....	250 kgs.
Ferro-manganese 60–65 per cent.....	80 "

(b) By the employment of the carburizing process:

Spiegeleisen.....	nil.
Ferro-manganese.....	12 kgs. or less.
Coke.....	50 "

The economy resulting from the employment of the carburizing process is here considerable; a similar relation holds good in the acid open hearth process. From the foregoing it is clear that the superiority of the carburizing process in regard to the question of cost becomes the more considerable, the higher the grade of hardness of the material to be produced. To the advantage that the harder sorts of steel can be produced with far greater ease and safety, there is to be added the very considerable economy in the cost of production, while by the old process the cost of production rose considerably with the grade of hardness.

During the month of July there was effected in the carburizing process another modification, which considerably improved one of our leading articles, viz., tires. We use for the manufacture of tires small ingots, containing sufficient material for one tire, which after being hammered into flat disks are perforated in the middle, this perforation being enlarged before the disk is reheated for rolling. This method requires

that the surface of the ingots is without any flaws, and it must be as well without any pores, as all these deficiencies can be seen afterward in the finished tire. The Siemens-Martin steel obtained by the carburization process does not show immediately after the casting an absolutely even surface. The carburized material was therefore not taken as material for tires.

Experiments were made to give the bath a small addition of aluminum, and in consequence of this all difficulties were removed. By adding about 0·04 per cent. aluminum an ingot was obtained which was absolutely free from porosities and eminently fit to be used for tires. Following up these experiments several solid castings were made out of the carburized material and these turned out equally satisfactory, being positively flawless.

The discussion was opened by Mr. P. C. Gilchrist, who said that he could freely indorse the Darby process; he had visited the works at Ruhrort, and saw it in operation, and found everything just as Mr. Thielen has described it. Mr. Suelus also agreed with Mr. Thielen, and said we were now able by means of this process to make a basic steel equal to any made from the best Swedish iron. The basic process allowed us to decarbonize, dephosphorize, and desiliconize to such an extent as to make an almost absolutely pure iron, and the Darby process furnishes us a means of recarburizing, which enables us to add exactly the amount of carbon required without adding anything which might be objectionable.

Herr Thielen was called on to close the discussion, but said there was nothing to discuss; all the speakers agreed with him, and he agreed with them. On the platform there was a handsome exhibit of a great many products made of the Darby steel, among which the most remarkable were cutting tools, scythes, taps, etc., which are usually made only of the best crucible steel.

PROF. KOCH'S CURE FOR CONSUMPTION.

IN the *Deutsche Medicinische Wochenschrift* (German Medical Weekly), Berlin, Professor Koch published on Nov. 14 an article entitled "Further Communications on the Cure of Tuberculosis and Experiments which Dr. Libbertz and Staff Surgeon Pruhl Performed Relating Thereto under Dr. Koch's Direction."

In this article Prof. Koch says that he is as yet unprepared to indicate the source from which the curative matter is derived. Neither is he ready to explain the method of preparation. The reason he gives is that the experimental work has not yet been brought to completion. He states, however, that the curative lymph itself can now be obtained from Dr. Libbertz, whose address is 28 Lueneburger Strasse, Berlin.

The lymph is described as a brownish transparent liquid. It is so prepared as to be proof against deterioration. When, however, it is diluted with water to the necessary degree for use, the matter is liable to decay. It is necessary, therefore, that the attenuations should be perfectly sterilized by heat and preserved in wadding covering, or prepared with a solution of phenol 50 per cent. strong. When taken into the stomach the curative matter proves to have no effect. It must be applied subcutaneously by means of a valveless syringe.

The kind of syringe recommended by Prof. Koch is one furnished with a small hollow rubber ball. This syringe approved itself to him during his bacteriological experiments. Its merits are that it can be easily and surely rinsed with absolute alcohol and kept in a perfectly aseptic condition. In thousands of cases, he says, where it has been used for subcutaneous injections, not a single abscess resulted. When the curative matter is applied to a patient, the usual course is to inject it under the skin of the back between the shoulder blades, and in proximity to the loins. The experiments show that human beings are much more susceptible to the effect of the new substance than are guinea pigs, which have been largely used in the course of the investigations. Two cubic centimeters of the fluid applied to a guinea pig produced little, if any, apparent effect.

Twenty five hundredths of a cubic centimeter, however, intensely affected a healthy, full-grown man who was subjected to experiment.

Prof. Koch experimented with the fluid upon his own body and describes the effect. He injected twenty-five hundredths of a cubic centimeter of the fluid under the skin of his upper arm. Three or four hours after the injection was made he experienced a contraction of the limbs and a marked feeling of lassitude. At the same time he felt a desire to cough, together with difficulty of breathing. These symptoms increased rapidly and, in the fifth hour, he experienced an unusually violent rigor. The shivering lasted for nearly an hour, and was accompanied with nausea and vomiting. The temperature of his body rose to 39 4° Centigrade. After a period of twelve hours the symptoms began to abate, the temperature of the body declined, and on the following day resumed its normal degree. The heaviness of the limbs and the feeling of lassitude, however, continued for some days, during which time the point on his arm at which the injection was made continued to be painful and remained red.

The experiments so far conducted show that the lowest limit of effective strength of the fluid in a healthy human body is one-hundredth of a cubic centimeter. When this amount is applied to a healthy human subject, it produces little or no reaction. The same results follow when fluid of this strength is applied to diseased persons who are suffering from other than tuberculous affections; but in persons affected with tuberculosis the same quantity produces a strong general and local reaction.

The general reaction consists of an attack of fever, which usually begins with shivering. The temperature of the body rises to over 39°, and, in some instances, even to 41° Centigrade. At the same time pains in the limbs are noticeable. The patient coughs, experiences much irritation and great exhaustion. Some patients also suffer nausea and vomiting. In some cases there is noticed a slight icteric (jaundice-like) coloring, or exanthema, resembling measles, on the chest or neck. The symptoms just described begin to manifest themselves four or five hours after the injection of the curative substance. They last from twelve to fifteen hours. The patient is not much affected by the attack induced by the fluid, and after it is over feels comparatively well, even better, in fact, than before the injection.

The second or local reaction produced by the injection of the fluid in a patient suffering from tuberculosis can best be observed in persons whose tuberculous affections are visible, as, for instance, in the case of persons suffering from lupus. The changes which ensue in these cases show, in a surprising manner, the specifically antituberculous effect of the remedy. Within a few hours after an injection of the fluid has been made under the skin of the back the lupus sores begin to swell and redden. During the fever which the patient experiences, as already described, the swelling and reddening of the sores increase, until finally the lupus tissue assumes, in places, a dark brown tint and a necrotic condition. After the subsidence of the fever the swelling of the lupus sores gradually decreases, and possibly disappears altogether within two or three days. Meanwhile, however, the lupus centers have become covered with an incrustation, formed by exuding serum which dries up as it reaches the air. These incrustations gradually form into scabs, which fall off after two or three weeks. In some instances the effect just described is produced after a single injection of the curative matter, when a red, smooth scar is left. These changes are absolutely limited in extent to such portions of the skin as are clearly recognized as lupus. In tuberculosis of the lymphatic glands, bone articulations, etc., these local reactions are less striking, but are still clearly perceptible to the eye and touch. In these cases there is swelling of the parts affected, and more pain than lupus patients suffer, while in the parts adjacent to the diseased center the surface also becomes red.

The reaction produced in the internal organs, especially the lungs, when the curative substance is injected, is not, of course, open to observation apart from the increased expectoration and cough.

In all the experiments after the first injections, if any tuberculous process existed in the body, the appearances already described supervened. Absolutely no exception was noted whenever a dose amounting to one-hundredth part of a cubic centimeter of the substance had been applied. One may assert with confidence, therefore, that the remedy may be considered an indispensable auxiliary to diagnosis, and, in doubtful cases, incipient phthisis can positively be diagnosed by its use, even if positive information of the nature of the disease cannot be obtained by the discovery of bacilli, or of elastic fibers in the sputum, or by a physical examination. Tuberculous affections of the glands, latent tuberculosis of the bones, doubtful skin tuberculosis, etc., can by the use of this fluid be easily and certainly diagnosed. Moreover, in cases of lung or joint tuberculosis, which have apparently passed off, it will be possible, by the use of the new substance, to ascertain with certainty whether the morbid process is really and absolutely ended.

Prof. Koch expresses the belief that his remedy will certainly prove a cure for incipient phthisis. Whether, however, the cure will be final and definite has not, he says, been clearly proved. Further experiments and continued use of the remedy will be necessary to determine this question.

The curative properties of the new remedy, Prof. Koch declares, are of still greater importance for diagnosis. What the fluid kills is not the tubercular bacillus, but the tubercular tissue. This fact indicates the well defined limits which the efficacy of the remedy will be able to reach. In other words, it can only influence living tuberculous tissue. It has no effect whatever upon dead tissue, such as dead caseous matter, necrotic bones, and the like. More than this, it produces no effect upon tissues which have already been killed by the application of the remedy. It is quite possible that such dead tissue may still contain living tuberculous bacilli. These may then be either expelled with the necrotic tissue, or it may be that under special circumstances they may again invade adjacent living tissues.

It follows, therefore, that tuberculous tissue that is still living must first be made to decay. When this has been accomplished, every effort must be made to remove the dead matter by surgery. In cases where this method is impossible, and secretion can only slowly proceed by the self-help of the organism threatened, the living tissue must, at the same time, be protected by continual applications of the remedy, so as to guard against the reimmigration of the parasites.

The fact that the remedy causes decay only of the tuberculous tissues, effecting exclusively living tissues, explains why the curative fluid may be applied in rapidly increased doses.

After the patient has been under treatment for a period of three weeks a dose of the fluid of five hundred times the strength of the original dose can be applied, for at the beginning, when a large quantity of living tuberculous tissue exists, a small quantity of the remedy suffices to produce a strong reaction, but each succeeding injection causes the disappearance of a certain quantity of tissue capable of reaction. It naturally follows, therefore, that increased doses are necessary to obtain the same degree of reaction. As soon as patients treated with increased doses experience as little reaction as non-tuberculous people, it may be assumed that all tuberculous tissue open to reaction is dead. Whether this conclusion is correct, time will show. For the present, however, Prof. Koch is convinced that this conclusion is a sound one.

In all cases of lupus so far treated the amount of fluid injected has been, in the first instance, one-hundredth part of a cubic centimeter. Time has then been allowed for the reaction to take its full course. After a period of from one to two weeks a second injection of the same amount has been made. This treatment has continued until the reaction grew weaker and finally ceased. In two cases of lupus of the face, the sores, after three or four injections, became scarred, and presented a smooth surface. Each one of these cases had suffered for many years and had been treated by other methods without beneficial results.

Persons suffering with tuberculosis of the lymphatic glands, bones or joints, have been treated with precisely the same success. There has been rapid healing in the milder cases and cases of recent development of the disease, while in severer cases the improvement, while slower, has been steady.

Patients with pronounced tuberculosis of the lungs have proved far more susceptible to the remedy than those suffering with surgical tubercular affections. Consumptives have, in almost every instance, manifested a strong reaction on greatly reduced doses. With such patients, therefore, a beginning should be made with doses of two one-thousandth parts of a cubic centimeter, or even with one one-thousandth part. From this small incipient dose one can advance to such quantities as the patient can easily bear. In the experiments that have been conducted, consumptives have, accordingly, first received a subcutaneous injection of one one-thousandth part of a cubic centimeter. Then, when the temperature increased, the same dose was applied daily until no further reaction occurred. Thereupon the dose was doubled, two one-thousandth parts of a cubic centimeter being injected regularly until again no reaction occurred. This method was continued with almost always an increase of one one-thousandth part of a cubic centimeter, or at most two one-thousandths, up to one one-hundredth part, and so on upward. In this way the patient would be brought to take very high doses almost without fever and almost imperceptibly to himself.

Consumptive patients who are still fairly strong reach increased doses much more quickly, and favorable results follow with corresponding rapidity. As a general rule, the coughing and expectoration are increased somewhat after the first injections. Then they become gradually less, and in the most favorable cases will ultimately wholly disappear.

In the cases experimented upon under the direction of Prof. Koch the expectorations gradually lost their purulent property and assumed a mucous character. The number of bacilli expelled usually decreases only when the expectorations begin to assume the mucous appearance. The bacilli then disappear entirely for a time, but on occasions again appear until expectoration totally ceases. At the same time the night sweats ceases, the patients begin to look better and to increase in weight. Patients who have been treated in the early stages of phthisis have all been freed from morbid symptoms within from four to six weeks, when they may be regarded as healed.

Consumptives with large cavities in their lungs will probably only experience benefit from the new remedy in exceptional cases, though most cases show temporary improvement.

Prof. Koch deprecates the mechanical and indiscriminate application of the remedy. He holds that it would be preferable that the treatment should be applied in suitable institutions, where careful observation would be possible.

Prof. Koch says that sufficient experience has not yet been collected regarding tuberculosis of the brain and the larynx and miliary tuberculosis to justify the expression of any opinion in regard to the efficacy of the remedy.

In all cases Prof. Koch emphasizes the necessity of early treatment. Only in incipient stages of disease, he declares, can the remedy fully develop its efficacy.

POISONING BY STALE OYSTERS.

A REMARKABLE case of poisoning by stale oysters occurred recently in Chicago, Dr. William M. Hibbard being the victim. The doctor was taken ill shortly after eating the oysters, and, according to the Chicago *Journal*, Drs. Frank Billings, McArthur and Frothingham were called in to attend the case. The patient rapidly grew worse, and it was decided to perform an operation, with the hope of saving his life. An incision was made in the stomach, and it was discovered that the poison had progressed too far; that the intestines had been so completely eaten up that the patient had only a few hours in which to live, and the operation was abandoned. The attending physicians stated that death resulted from ptomaines. Dr. Liston H. Montgomery said that ptomaines was an alkaloid that was generated during the progress of the decay of animal matter, and possessed very dangerous properties. In other words, it was a putrefaction of albuminous nature, a ferment very poisonous. It forms in human bodies, and the exclusion of air favors its formation. It produces death like morphine.

RECIPES FOR DYERS.

THE following are mostly translations from foreign sources. We do not guarantee the results from these recipes, but give them for the purpose of showing our readers what their foreign competitors are doing:

DARK BROWN ON COTTON.

For 100 lb. cotton. Mordant at the boil with

Catechu	10 lb.
Logwood extract	2 lb.
Magenta	¼ lb.

for three hours, then darken in a new bath with

Bichromate of potash	3 lb.
Soda	2 lb.

DARK FAWN ON WOOL.

For 100 lb. wool. Work in a bath with

Tartar	3½ lb.
Sumac	5½ lb.
Fustic	13 lb.
Brazil wood	10 lb.

for 1½ hours at the boil. Sadden with

Copperas	1 lb.

Boil one hour longer, then add

Brazil wood	5 lb.
Sanders' wood	1 lb.

and boil ¾ hour longer.

DARK BROWN ON WOOL.

For 100 lb. Mordant by boiling for 1½ hours with

Bichromate of potash	3 lb.
Tartar	1½ lb.

Dye with

Fustic	50 lb.
Logwood	5 lb.
Sanders' wood	17 lb.

for 1½ hours at the boil. Sadden by adding

Copperas	5 lb.
Bluestone	2½ lb.

Work for five minutes at the boil, allow to stand for ten minutes, lift and dry.

DARK OLIVE BROWN ON WOOL.

For 100 lb. wool. Dye in a bath at the boil for 1½ hours with

Fustic	55 lb.
Logwood	10 oz.
Sumac	1¼ lb.
Cloth red B	6 oz.
Fast brown G	½ lb.
Fast yellow	1 oz.

Darken in a bath of

Bluestone	4 lb.
Copperas	2½ lb.

for ten minutes, wash and dry.

CHEAP BLACK ON MIXED COTTON AND WOOL CLOTH.

Boil in a bath of

Logwood extract	25 per cent.
Fustic extract	4 "
Soda	13 "
Bluestone	8 "

Work at 120° F. for some minutes, then raise to boiling, until a good black is got, after which enter in a new bath containing

Bichromate of potash	4 per cent.

BLACK ON WOOL FROM ALIZARINE COLORS.

A: Red Shade Black.

For 100 lb. wool. Mordant by boiling from 2 to 2½ hours in a bath containing

Bichromate of potash	3 lb.
Tartar	2½ lb.

Dye in a bath containing

Alizarine blue WX	32¼ lb.
Cœruleine W	1¼ lb.
Alizarine orange W	3 lb. ¼ oz.

B: Reddish Shade.

Mordant as before. Dye with

Alizarine blue WX	32¼ lb.
Cœruleine W	1¼ lb.
Alizarine orange	2½ lb.

C: Blue Black.

Mordant as before. Dye in a bath containing

Alizarine blue WX	36½ lb.
Cœruleine W	1½ lb.
Alizarine orange W	1½ lb.

Enter the wool in the cold, work for half hour, then gradually raise to boil and dye boiling for 1½ hours. Then lift, wash and dry.—*Textile Mercury.*

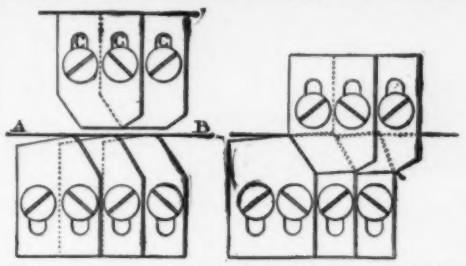
MACHINE FOR MAKING LATTICE WORK.

THE machine represented herewith is designed for making lattice work mechanically by cutting it directly out of a sheet of metal and automatically extending the network thus formed.

The principle is as follows:

Let us suppose that we cut a series of longitudinal slits in a sheet of paper in the direction of its length. Then by pulling the two uncut edges in opposite directions we shall have a sort of trellis with superposed meshes. But if we free the edges the paper will return to its plane form. The machine, then, has not only to cut slits in the sheet of metal, but also to give to each mesh the form that it is to preserve. This work is effected by means of two rows of cutters, one above the other, but in different planes, and between which the metal is seized. Figs. 2 and 3 show the positions taken by the cutters.

In Fig. 2 they are ready to receive the band, A B,



FIGS. 2 AND 3.—POSITIONS TAKEN BY THE CUTTERS.

and in Fig. 3 they have finished the work, formed the meshes and are ready to recede.

The metallic sheets employed are of soft steel, and are treated in bands 7 inches in width and 8 feet in length.

These bands, according to the sizes of the meshes, furnish a lattice of from two to four feet in width, and of very nearly the initial length. In Fig. 4 may

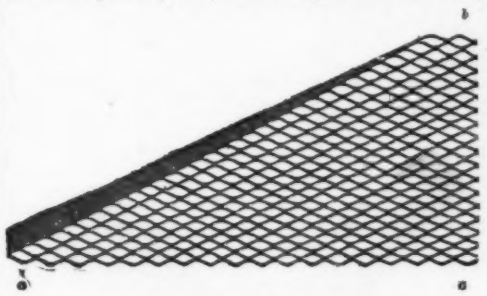


FIG. 4.—A PARTIALLY WORKED BAND.

be seen a band partially worked. It advances from left to right parallel with the line, *a b*, and the first blow produces a single aperture, the second, two and two lozenge shaped meshes, the third, three and six meshes, and so on. Figs. 5 and 6 represent finished lattices.

The machine is provided with two jaws in which the

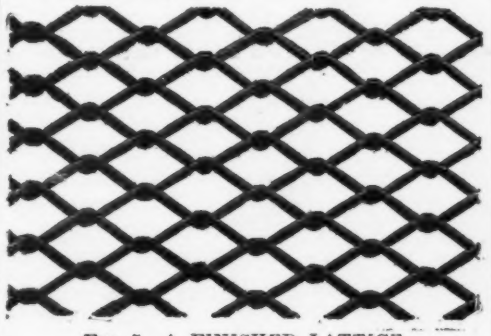


FIG. 5.—A FINISHED LATTICE.

cutters are fixed. The upper moves in a vertical plane under the action of eccentrics.

Two of these latter are fixed upon the main shaft by joints and receive, through gearings placed to the left of the machine, motion from the driving shaft. The lower jaw moves freely in a longitudinal direction between its guides, and as the edges of the cutters are oblique, those below are thrust from right to left, while those above descend upon them and push the metal until these latter have risen. A large cam placed

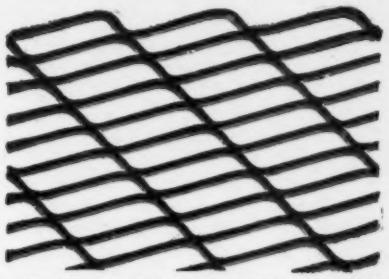


FIG. 6.—LATTICE TO REPLACE LATH WORK.

projectingly over the right afterward brings back the lower jaw and its cutters to the initial position.

When the work is begun, the band is introduced at the left. The first cutter acts alone, and in the first place forms its aperture and then depresses the edges of it until the necessary form has been obtained. The second stroke gives two meshes, the third, four meshes, the fourth, six meshes, and so on, until the band, which advances obliquely by one tenth inch or more per stroke, has reached its extremity. The work is, therefore, entirely automatic.

The machine herewith represented produces about four thousand feet of lattice work per day of ten hours. With 4 inch meshes the bands give a lattice 4 feet in width and 7 in length.

Those lattices are employed with much success as a substitute for the lathwork that is ordinarily used for the reception of plaster. Fig. 6 gives a type of this kind of lattice, which has very long and not very wide meshes.

Lattices with lozenge shaped meshes, like those shown in Fig. 5, are principally used for partitions.—*Le Genie Civil.*

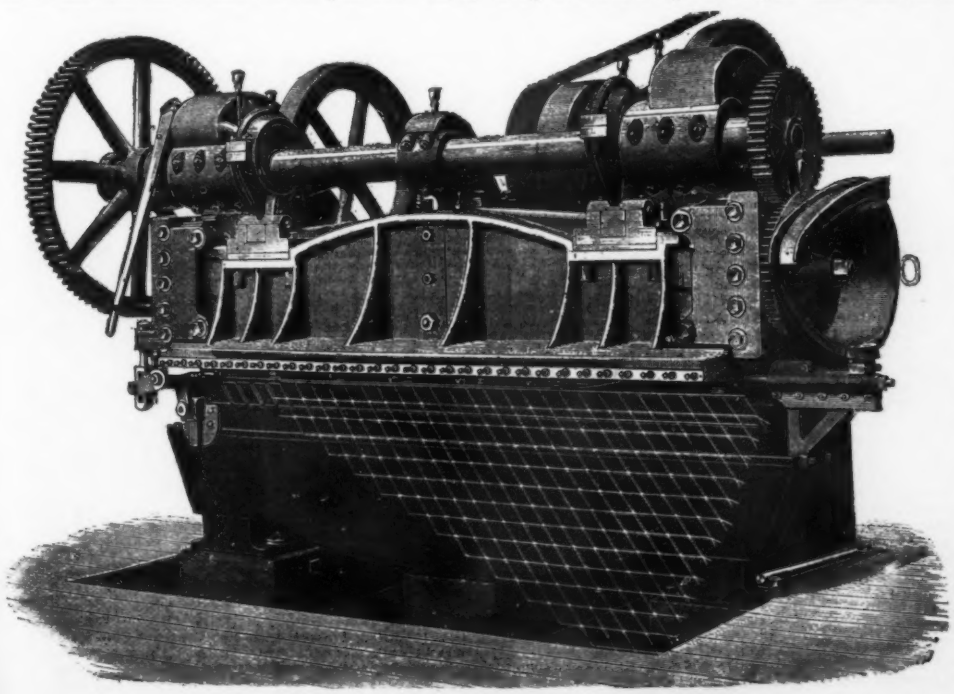


FIG. 1.—MACHINE FOR MAKING LATTICE WORK.

ELECTRIC WELDING APPLIED TO THE MANUFACTURE OF PROJECTILES.*

By Lieut. W. M. WOOD, U. S. N.

I AM asked to-night to tell you something of a new process which has been originated and developed within the past year; a new and important application of an art in itself new, electric welding.

At this moment, when there is so general an interest manifested throughout the country in the question of the nation's arms and defenses, this new invention, which bids fair to supersede and immensely cheapen existing methods, is sure to claim its share of attention, both from experts in ordnance and the general public.

Before entering upon the subject proper, I wish to say a few words on the general state of military art and on the production of projectiles in particular. For nearly a generation we have stood aside and watched others pass us in the race; forgetting what we knew so well at the close of our late war, until now we have finally awakened to find ourselves relegated to almost the lowest place among the nations of the earth. To use a lowly simile, we might have been, until very recently, likened to a crab which has just shed its shell; rich and fat, but helpless—unable to assert our rights or aid our friends in time of need.

Since the earliest times man's ingenuity has been taxed, first to improve his weapons, next his defenses. The race between projectiles and armor commenced with the bow and arrow or sling as against the rawhide covered buckler. It has passed by gradual evolution through an infinite number of stages; sometimes the armor, sometimes the projectile ahead; generally the latter. Indeed, at times, the projectile has been so much ahead as to cause the total abandonment of armor. This happened when the bullets and slugs from the crude blunderbuss of the middle ages made the matchless armor of the warrior of the day worse than useless. Some authorities are inclined to believe that an analogous case exists now, and that on the sea, at least, it is folly to burden vessels with an enormous weight of armor which can be pierced so easily by the heavy projectiles thrown by the enormous, high powered guns in use. To the casual observer this may seem true, but, on the other hand, we must not forget that armor *does* protect against the great number of moderate sized projectiles, and that if you can even only partially protect the vitals of your structure, it is much gained. We must also remember that these latest developments of armor and projectile have never been pitted against each other in actual warfare, and that there will be a vast difference between firing through a target at point blank range and at a swiftly moving, rolling, wavering object, a mile or more away, which is at the same time firing back at you.

At the present moment it looks as though the projectile was about to gain another point over armor and become a still more important factor. Artillerists on shore are now directing their attention largely to the use of breechloading rifled howitzers or mortars. These guns are fired at a great elevation, rarely less than forty-five degrees, and frequently at sixty degrees. The projectile has, consequently, a high curved trajectory and plunges down on and through the decks of vessels or behind parapets. The decks of men-of-war are frequently not protected at all, except over the engines, boilers, and magazines, where a curved armored deck is used with a maximum thickness of from 4 in. to 6 in. Four inches is the greatest thickness of the curved protective decks of our new cruisers, and is the only armor those now afloat have.

The varying ranges of these howitzer-thrown projectiles are given by increasing or decreasing the weight of the powder charge.

In some recent experiments made by Krupp, in Germany, very satisfactory results have been obtained by projectiles thrown from this class of gun against horizontal targets representing the armored decks of ships.

The defenses of Boston and our other seaboard cities

* A paper read before the Society of Arts, Institute of Technology, Boston, October 23, 1890.

are to comprise a large number of guns of this class. They fire both armor-piercing and common shell. Redoubts and turrets on shore can be armored as heavily as you please, or guns and troops can be defended by that most excellent protection, the earthwork. Afloat, however, where every pound carried is a matter of serious consideration, the problem is a very different one, and the weight of armor must necessarily be limited by the size of the vessel. A proper navy, however, will always be made up of a number of vessels of various kinds, more or less dependent on each other, from the gigantic battle ship fully protected by the heaviest armor down; including the partially protected cruisers, fast unprotected vessels, dispatch boats, converted merchantmen used as commerce destroyers or transports, torpedo boats, etc.

Troops in the field are like the unarmored cruisers, torpedo boats and converted merchantmen, practically unprotected.

For use against these various defenses and where there are no defenses except distance and advantage of position, there are in use three general classes of projectiles (not considering the more or less experimental dynamite and other high explosive shells). They are, 1st, the *armor-piercing shell*, used solely, as its name indicates, against heavy armor; 2d, *common shell*, used against unprotected vessels and troops, for bombarding cities and earthworks, for target practice, etc.; 3d, *shrapnel*, so named from its inventor, extensively used in field operations on shore against bodies of troops and at sea against open boats, torpedo boats or any unprotected body of men.

Leaving the ordinary bullet of the shoulder rifle out of the question, these projectiles range in weight from those of a single pound to the gigantic missiles of the 110 ton gun, which weigh about one ton and are driven by almost half a ton of powder.

Now in order to show how much is gained in the construction of projectiles by the Thomson electric welding process, I will briefly describe the present methods of manufacture.

1st. The Armor-Piercing Shell. To fulfill the government requirements these must be made of a fine quality of steel, capable of being made very hard and still be tough. In the first operation, it is forged or rolled into a rough solid blank. After this it is placed in a lathe and turned off accurately on the outside and the powder chamber bored in the axis of the shell from the base, as in this specimen. This opening is then closed by a carefully fitted screw plug, in the center of which is a smaller threaded hole into which fits the percussion fuse which explodes the shell on impact. A groove is now turned in the outside near the base and knurled or roughened. This is for the copper rotating band, and the roughening is to prevent its slipping when the copper enters the rifling of the gun. Next the shell is hardened by one of the various processes which are more or less satisfactory, and finally the copper band is forced into place by hammering or hydraulic pressure and turned off true to gauge. This completes the projectile, and you will readily understand that all of this work is slow, tedious and expensive. Any one who is familiar with the operation of machining high carbon or tool steel will appreciate this. As a matter of fact, a 6 in. armor-piercing shell which only weighs 94 lb. costs in the neighborhood of $65 or $70.

Next come common shell. These at present are cast either of steel or iron, but even in this cheap form of production many difficulties are met with. In the first place, the shell usually has but one small opening to the inside powder chamber, and this only allows the use of a single "print" to hold up the core which forms the interior cavity; consequently, when the molten metal flows in, it pushes this core out of place, and the resultant casting is eccentric—thin on one side, thick on the other—frequently so much so as to cause it to be discarded entirely. When the castings are received from the foundry they are first carefully calipered on the inside by a skilled operator, who uses a delicate instrument called a "star gauge," which expands within and enables him to determine the amount the casting is out of true, which he marks on the shell. It is then passed to the hands of the machinist. He is obliged to place it in his lathe eccentrically, so that the outside will be turned true with the inside; and you can imagine that even after all this care they are never perfectly concentric. Another serious difficulty met with in the cast projectiles is the liability to small blowholes or porosity, which, though they sometimes escape detection, always cause the rejection of the projectile when discovered. Through these holes the gases of the charge might be driven and thus cause a premature explosion of the shell in the gun. Steel shell of this description, of 6 in. caliber, cost about $30 each. Like the armor-piercing shell, they are fitted with rotating bands and fuses, but are not hardened.

We now come to the shrapnel. It was originally invented for use in the smooth-bore guns of the past, and was then a hollow sphere filled with small bullets, around which was poured melted sulphur as a matrix. A small powder chamber for a bursting charge was left in the middle. It was provided with a time fuse which could be set so that the shell would explode at the desired moment in its flight, scattering its contents and fragments in the face of the enemy. So far, there seems to have been no very satisfactory shrapnel made for rifle guns. The difficulty is that the head or base has to be screwed on after the body of the shell has been filled with the bullets and matrix. This construction weakens the projectile very much at this point, and the head or base is apt to blow out without bursting the body of the shell or scattering the bullets, especially as the walls of the projectile have to be made thick enough to stand the threading.

Hoping I have now made clear the general state of the art, I will explain wherein this new process differs, and will endeavor to illustrate it by the specimens I have here.

First, instead of the solid, rough-forged ingot, we have these three component parts, which when welded together will form a 6 lb. armor-piercing shell. Each piece is now finished to exact size, except that there is a little extra length to allow for the take-up in welding. The head and base pieces are forged in dies to shape; the central portion is simply a piece cut from a length of solid-drawn steel piping. It has all the additional strength due to the fibrous skin inside and out caused by the drawing process. To join these three pieces, they are clamped into a form of electric welding machine designed for the purpose, and in less than a minute are joined together and made a homogeneous mass like this.

It now only remains to grind off the two burrs which you see in this specimen, and cut in the groove for the rotating band. The front one of these burrs may be used to form an enlargement used in many forms of projectiles, called technically a "bourillet." It supports the front portion of the shell in the bore of the gun, the remainder not touching except at the rotating band. The other burr may be removed at the same time the rotating band groove is cut. The fuse hole has already been cut and threaded in the base piece. The shell is now ready for the hardening process. I wish to call attention here to the fact that the burrs are allowed to remain on the inside and thus form strengthening ribs which help materially to support the shell against the great crushing strain it receives on impact. You will see that we have thus formed a stronger and better shell with minimum of labor on the individual parts and a few seconds' work to join them together.

In order to illustrate the wonderful strength that may be gained by this welding process, I have here a shell which was constructed exactly as I have shown. It was fired through a 3 inch plate of iron at the naval proving grounds at Annapolis recently. You will see that it has not changed its shape in the slightest degree, nor has it even lost the copper rotating band, which was carried through the hole with it. Here is another which shows a still more remarkable result. This projectile was fired against heavy steel armor which has a resistance of about 75 per cent. more than iron and which was much heavier than a projectile of this size could be expected to perforate. It, however, penetrated 5 inches, and then, owing to the elasticity of the oak backing of the plate, was thrown back about 30 feet, as perfect in condition as before it was fired from the gun. The experience of the welding company has been that the metal seems to be strengthened at the point of welding, and this certainly seems to justify the supposition.

After accomplishing results like this, you will see that the manufacture of the common shell becomes a very simple matter. By the welding process, it is quite feasible not only to join iron to high carbon steel, but to weld wrought iron or steel to steel castings or even to cast iron. Hence, in this case, it is only necessary to substitute common iron or low carbon steel tubing and stamped or cast heads and bases and perform the welding operation. The shell which is thus cheaply put together has all the advantages of wrought and none of the disadvantages of cast metal. If made of low steel, it may even be hardened to a certain extent, and thus have more or less efficiency against thin armor.

In regard to the shrapnel, a single look at this section will show the problem and how it has been met. This is from a design for the United States army 3·2 inch field piece. The head and base are steel castings, which have been heated and compressed to give them density. The body is drawn steel tubing one-fourth inch thick. The projectile was built as follows: First, the head was welded on to the body. Next, the brass tube that carries the flame from the fuse to the powder chamber at the base was crimped in at the upper end. The half-formed projectile was then inverted and the bullets placed within and the matrix poured about them. Next the diaphragm which forms the front end of the powder chamber was put into position and the other end of the tube crimped in. The shell is now ready for the final weld, and you will notice that the base piece is provided with a shoulder, which after the weld is made will press closely upon the diaphragm and support it against the shock of the discharge. After the second weld is made, the shrapnel has an unbroken surface inclosing its deadly bullets, and, like the other shell, is ready to be fitted with rotating band and fuse.

To summarize: these shell can be produced in the method I have described so that a wrought steel projectile can now be manufactured at a less cost than a cast iron one, which except for target practice is almost worthless; and as for armor-piercing shell or even moulded steel shell, there can be no comparison as to cost of production. This same principle can also be applied to solving a still more difficult problem, and one which has hitherto baffled the skill of the inventor, viz., the welding the solid heads on to the large brass cartridge cases now used with the projectiles of rapid fire guns. A rapid fire gun is one having a non-recoil and pivoted mount. It is aimed and fired from the shoulder like an old fashioned swivel. They range in size up to as large as the 6 inch gun. The ammunition is fixed just the same as the bullet and cartridge of a shoulder rifle. At present, these brass cases are constructed with great difficulty and at much expense by drawing up from the solid ingot, and no one is prepared to make those of the large sizes in this country. By the Thomson process, which also welds brass and copper, this will be an easy matter and the cost should be less than one-quarter that now paid by the government for those they are obliged to import.

In conclusion, I will say that it is a well known fact among ordnance experts that the breech mechanism and the principle of the construction of the present high-powered guns are entirely due to American invention, which was, however, forced out of the country by lack of appreciation and was taken up and developed in Europe. I believe the day has come at last when our military inventors will not have to seek their encouragement entirely abroad, and I think that in the very near future our government will be supplied entirely by cheap and effective projectiles of the kind I have shown you to-night.

NEW FEATURES IN ARMAMENT.

THE value of high angle fire against ships' decks has been recognized for many years in different countries. We have adopted it for the defense of coaling stations in a measure. Italy, however, appears to have reduced it to a system to an extent which we think distances other powers. We give in Fig. 4 a drawing showing an

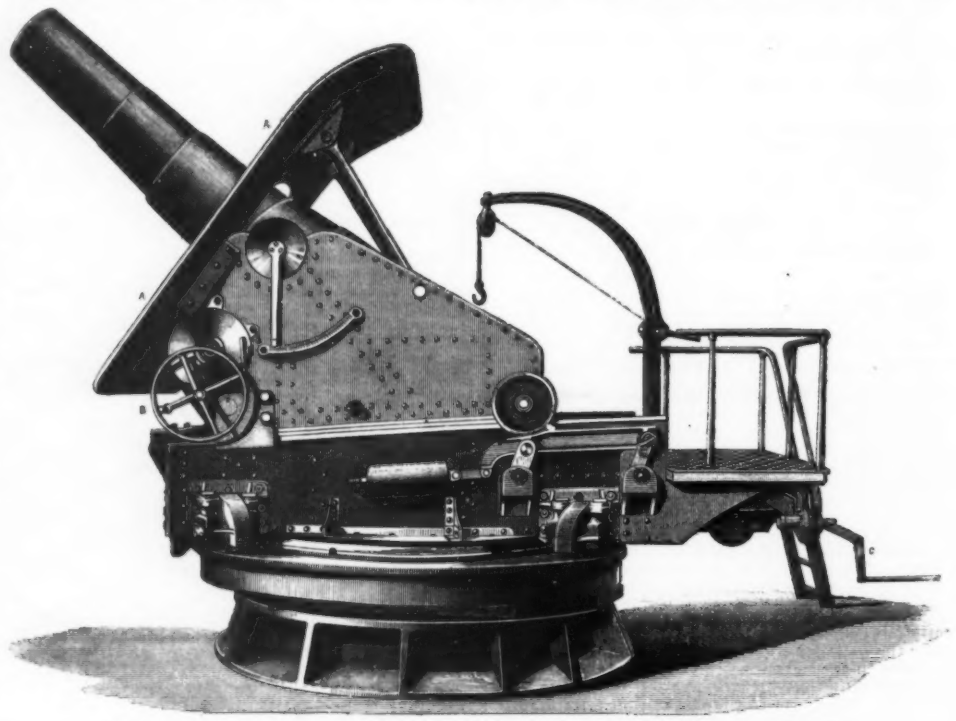


FIG. 4.—HIGH ANGLE BREECH-LOADING HOWITZER.

11 in. howitzer mounted on an Elswick carriage, taken from a photograph of a new design. This piece is fired at varying elevations, from 7 deg. depression up to about 45 deg. elevation. A previous pattern ranged from 45 deg. to 70 deg. elevation. The shield shown is fixed to the carriage and recoils with it. The gun is shown at nearly the maximum elevation, and is nearly close up to the top of the aperture of the shield AA, though when the gun is horizontal the position of the shield is such that the aperture is still nearly closed. In recoil the gun and carriage move in the direction of the surface of the platform or slide. There are two front and two rear rollers which come into play, owing to the pull of the spring in the box G, and the tilting bar H, which lift up the rear end of the carriage when it runs forward, but during recoil the gun's recoil strain overcomes the tilting power, and the carriage slides on the plane surface of the platform. The recoil resistance is provided by means of a pair of hydraulic presses under the carriage, between the two beams of the slide, and parallel to their surface. The hand wheel B at the forward end of the carriage is for elevation, and the crank C at the rear of the platform is for training.

The guns for the hydro-pneumatic carriage of the previous pattern, before mentioned, and those of the newer mount—Figs. 1 and 2—are, or may readily be, interchangeable in the two mounts.

The chief particulars relating to the gun and ammunition are as follows:

Weight of projectile		478 lb.
Weight of gun charge		44 lb.
Bursting charges	Penetrating shell	21 lb.
	Common shell	64 lb.
Rifling		64 grooves.
System of breech		Parallel interrupted screw and cup gas check.
Weight of gun		11 tons.

The carriages are very easily worked Four men, or even three, can do the training, elevating, and sighting, while the loading in either design requires about four men. About seventy of these high angle carriages taking the two designs together have been supplied.

The following is a detailed account of the hydro-pneumatic high angle mount:

The principal parts of the carriage are shown in detail in Figs. 2 and 3: (1) The circular platform AA, or turntable, which is placed in a pit, with its top surface level with the ground. (2) Two steel frames B B, firmly fitted to the above, on which are the slide surfaces for the carriage—Figs. 1 and 2. (3) The carriage A, which consists of four steel castings bolted together at the center, and fitted with bearings and capsquares for the howitzer trunnions, and with sockets for the recoil rams. (4) Two recoil cylinders H, and rams J. (5) The live rollers S, which are held in place by the live roller ring, and run between the upper and lower roller paths. (6) The rack fixed to the lower roller path, with the training gear working into it, and carried on the circular platform. (7) The training gear. (8) The elevating gear.

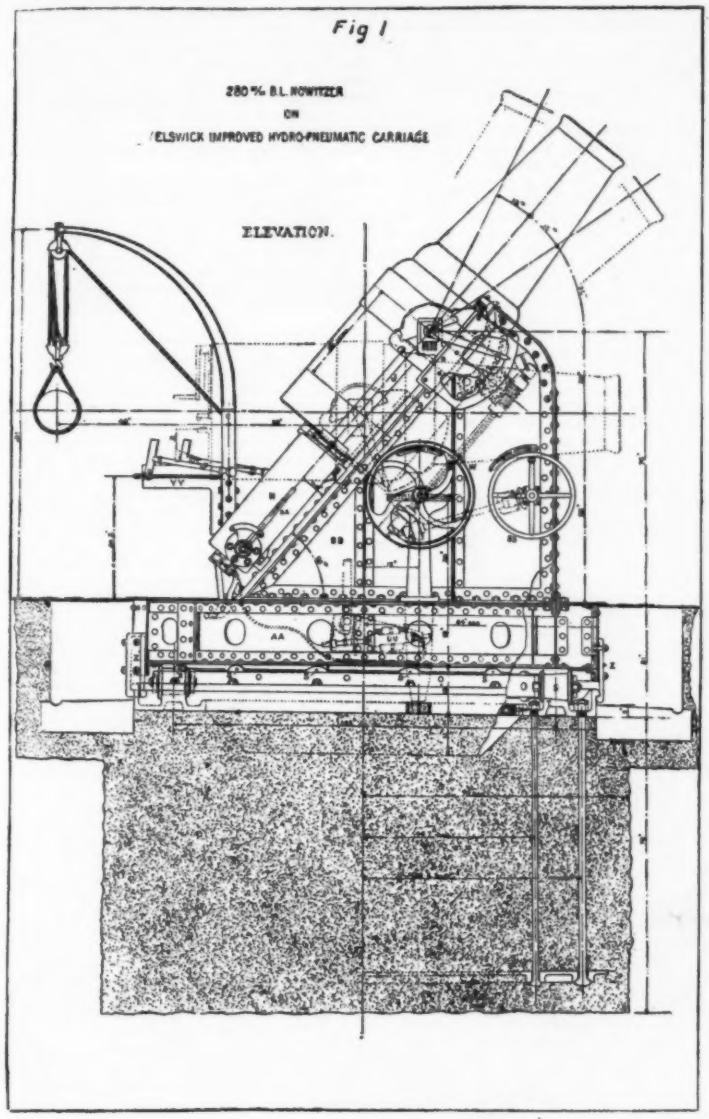
Besides the above there are many minor fittings such as: (*a*) A pump V V on the left side of the platforms for bringing the gun down without firing it. (*b*) A loading crane Y Y, which is made to swing round to serve the howitzer. Attached to this is a folding loading stage, which enables the men to mount to change the charge when the howitzer is up. (*c*) Indicator and direction plates as guides in working the carriage.

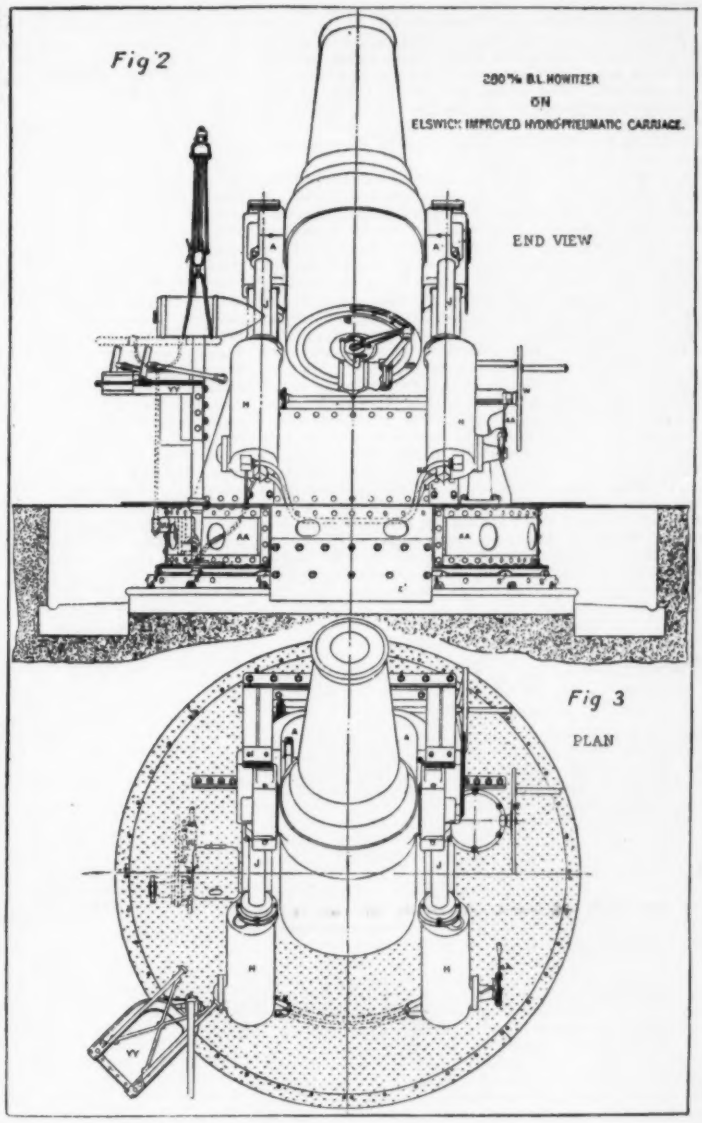
The hydro-pneumatic cylinders H are bolted to the frames B B of the circular platform. Each cylinder has two chambers, one, the recoil cylinder, containing the recoil ram J, the other containing the necessary supply of liquid and air. The two chambers are connected by a recoil valve and a by-pass or elevating valve. The recoil cylinders are provided with spring-loaded valves, so that the recoil of the gun is resisted by an equal force throughout the recoil. This force is estimated to be 1,700 lb. per square inch on the recoil rams. The recoil valves permit the liquid to pass from the recoil cylinders to the air chambers, but not to pass back again. For the liquid to pass back again when the howitzer has to be raised, a by-pass valve is provided, and this is opened by the hand lever A. Near the middle of each cylinder, on the top side, is an air cock, and a filling cock is fitted on the bottom side of the right cylinder. The recoil rams are secured to the trunnion blocks by stout screwed pins.

The work of training is extremely small, a force of only about 8 lb. or 10 lb. being required for each ton of weight moved. Thus, in the present case the revolving weight of the howitzer and carriage is about twenty tons, and the horizontal force required to produce motion is 180 lb. if applied at the radius of the roller path, or 12 lb. if applied on the rim of the training handwheel. The power required on the handwheel to elevate or depress is about 8 lb.

The drawing, Fig. 5, shows the arrangement of a battery of howitzers for attack of ships' decks by high angle fire. It will be seen that the pieces themselves, mounted behind a high parapet on ground of considerable command, are not open to direct attack from ships, and practically they are not open to attack at all from them. It is presumed that in such a case no shield would be fixed on the carriage. They are enabled to fire accurately by means of directions given them by the telephone connection, marked in the engraving, with the observing station far to the right.

Very successful experiments have been carried out at Spezia with vertical fire against moving objects. We have in England made experiments with vertical fire, but not, we believe, against moving objects. Major Watkin has confidence in good results being obtained with vertical fire against moving targets on his system. Under the most perfect direction, however, the time of





HIGH ANGLE HOWITZER CARRIAGES.

FIG. 5.—HIGH ANGLE HOWITZER BATTERY.

flight of the projectile must enable the wind to act on it, which, with the movement of the ship, constitute peculiar difficulties. Against vessels at anchor we have for very many years held that vertical attack is very formidable. We do not expect a projectile of any kind to pass right through the ship and out at her bottom, because even an armor-piercing projectile, if it had falling velocity enough for such an effect, would probably be broken up long before it reaches the bottom. Shells at high angles seldom fall truly point first. Now, a shell striking truly point first at an angle to an object is much more likely to break than in a direct blow, but if the shell's axis is also at an angle to its path, fracture is much more easily effected, and we believe that in many cases this would take place in passing through an upper structure before the armored deck is reached. The effect produced, then, by any description of projectile would be the fracture and disorder caused in the complicated machinery with which modern ships are now fitted. It would be a serious, but not, we think, a fatal injury.

Other new elements which are carried out more fully in the Italian service than in our own are found in the swift unarmored crusier the Piemonte, built and equipped at Elswick. The vessel herself possesses some unprecedented powers. Her displacement is 2,500 tons only, and her length 300 ft. Her speed is 21 knots, and she is able to steam at 10 knots for a distance of 13,500 miles on the coal she carries. She has an armored deck, and on this and the special arrangement of engines and coal, combined with her high speed, she depends for protection. Her offensive powers are very great. She carries the following armament: Six 6 in. quick-firing guns, six 4¾ in. quick-firing guns, ten 6 pounder Hotchkiss guns, six 1 pounder Hotchkiss guns, four 10 mm. Maxim guns, and three torpedo tubes. This armament is distributed in such a way that four of the quick-firing guns fire right ahead, when desired, two being under the forecastle, and two upon the after end of it. Four can fire right aft, two being mounted on the fore end of the poop and two under it. Two 6 pounders and two of the 1 pounders are placed on the top sides. Each of the two lower tops carries two 1 pounder Hotchkiss guns, and each of the two upper tops two 100 mm. Maxim guns. One torpedo tube fires directly ahead, and one from each broadside.—*The Engineer.*

THE ELECTROMAGNET.[1]

By Professor SILVANUS P. THOMPSON, D.Sc., B.A., M.I.E.E.

INTRODUCTORY.

AMONG the great inventions which have originated in the lecture room in which we are met are two of special interest to electricians—the application of gutta-percha to the purpose of submarine telegraph cables and the electromagnet. This latter invention was first publicly described, from the very platform on which I stand, on May 23, 1825, by William Sturgeon, whose paper is to be found in the forty-third volume of the Transactions of the Society of Arts. For this invention we may rightfully claim the very highest place. Electrical engineering, the latest and most vigorous offshoot of applied science, embraces many branches. The dynamo for generating electric currents, the motor for transforming their energy back into work, the arc lamp, the electric bell, the telephone, the recent electromagnetic machinery for coal mining, for the separation of ore, and many other electro-mechanical contrivances, come within the purview of the electrical engineer. In every one of these, and in many more of the useful applications of electricity, the central organ is an electromagnet. By means of this simple and familiar contrivance—an iron core surrounded by a copper wire coil—mechanical actions are produced at will, at a distance, under control, by the agency of electric currents. These mechanical actions are known to vary with the mass, form, and quality of the iron core, the quantity and disposition of the copper wire wound upon it, the quantity of electric current circulating around it, the form, quality, and distance of the iron armature upon which it acts. But the laws which govern the mechanical action in relation to these various matters are by no means well known, and, indeed, several of them have long been a matter of dispute. Gradually, however, that which has been vague and indeterminate becomes clear and precise. The laws of the steady circulation of electric currents, at one time altogether obscure, were cleared up by the discovery of the famous law of Ohm. Their extension to the case of rapidly interrupted currents, such as are used in telegraphic working, was discovered by Helmholtz; while to Maxwell is due their further extension to alternating or, as they are sometimes called, undulatory currents. All this was purely electric work. But the law of the electromagnet was still undiscovered; the magnetic part of the problem was still buried in obscurity. The only exact reasoning about magnetism dealt with problems of another kind; it was couched in language of a misleading character; for the practical problems connected with the electromagnet it was worse than useless. The doctrine of two magnetic fluids distributed over the end surfaces of magnets, under the sanction of the great names of Coulomb, of Poisson, and of Laplace, had unfortunately become recognized as an accepted part of science, along with the law of inverse squares. How greatly the progress of electromagnetic science has been impeded and retarded by the weight of these great names it is impossible now to gauge. We know that for all purposes, save only those whose value lies in the domain of abstract mathematics, the doctrine of the two magnetic fluids is false and misleading. We know that magnetism, so far from residing on the end or surface of the magnet, is a property resident throughout the mass; that the internal, not the external, magnetization is the important fact to be considered; that the so-called free magnetism on the surface is, as it were, an accidental phenomenon; that the magnet is really most highly magnetized at those parts where there is least surface magnetization; finally that the doctrine of surface distribution of fluids is absolutely incompetent to afford a basis of calculation such as is required by the electrical engineer. He requires rules to enable him not only to predict the lifting power of a given electromagnet, but also to guide him in designing and constructing electromagnets of special forms suitable for the various cases that arise in his practice. He wants in one place a strong electromagnet to hold on to its armature like a limpet to its native rock; in another case he desires a magnet having a very long range of attraction, and wants a rule to guide him to the best design; in another he wants a special form having the most rapid action attainable; in yet another he must sacrifice everything else to attain maximum action with minimum weight. Toward the solution of such practical problems as these the old theory of magnetism offered not the slightest aid. Its array of mathematical symbols was a mockery. It was as though an engineer asking for rules to enable him to design the cylinder and piston of an engine were confronted with receipts how to estimate the cost of painting it.

Gradually, however, new light dawned. It became customary, in spite of the mathematicians, to regard the magnetism of a magnet as something that traverses or circulates around a definite path, flowing more freely through such substances as iron than through other relatively non-magnetic materials. Analogies between the flow of electricity in an electrically conducting circuit and the passage of magnetic lines of force thorugh circuits possessing magnetic conductivity forced themselves upon the minds of experimenters, and compelled a mode of thought quite other than the previously accepted. So far back as 1821, Cumming[1] experimented on magnetic conductivity. The idea of a magnetic circuit was more or less familiar to Ritchie,[2] Sturgeon,[3] Dove,[4] Dub,[5] and De la Rive,[6] the last named of whom explicitly uses the phrase, "a closed magnetic circuit." Joule[7] found the maximum power of an electromagnet to be proportional to "the least sectional area of the entire magnetic circuit," and he considered the resistance to induction as proportional to the length of the magnetic circuit. Indeed, there are to be found scattered in Joule's writings on the subject of magnetism some five or six sentences which if collected together constitute a very full statement of the whole matter. Faraday[8] considered that he had proved that each demagnetic line of force constitutes a closed curve; that the path of these closed curves depended on the magnetic conductivity of the masses disposed in proximity; that the lines of magnetic force were strictly analogous to the lines of electric flow in an electric circuit. He spoke of a magnet surrounded by air being like unto a voltaic battery immersed in water or other electrolyte. He even saw the existence of a power analogous to that of electromotive force in electric circuits, though the name, "magneto-motive force," is of more recent origin. The notion of magnetic conductivity is to be found in Maxwell's great treatise (vol. ii., p. 51), but is only briefly mentioned. Rowland,[9] in 1873, expressly adopted the reasoning and language of Faraday's method in the working out of some new results on magnetic permeability, and pointed out that the flow of magnetic lines of force through a bar could be subjected to exact calculation; the elementary law, he says, "is similar to the law of Ohm." According to Rowland, the "magnetizing force of helix" was to be divided by the "resistance to the lines of force;" a calculation for magnetic circuits that every electrician will recognize as precisely as Ohm's law for electric circuits. He applied the calculations to determine the permeability of certain specimens of iron, steel, and nickel. In 1882,[10] and again in 1883, Mr. R. H. M. Bosanquet[11] brought out at greater length a similar argument, employing the extremely apt term "Magnetomotive Force," to connote the force tending to drive the magnetic lines of induction through the "magnetic resistance" or, as it will be frequently called in these lectures, the magnetic "reluctance" of the circuit. In these papers the calculations are reduced to a system, and deal not only with the specific properties of iron, but with problems arising out of the shape of the iron. Bosanquet shows how to calculate the several resistances (or reluctances) of the separate parts of the circuit, and then add them together to obtain the total resistance (or reluctance) of the magnetic circuit.

Prior to this, however, the principle of the magnetic circuit had been seized upon by Lord Elphinstone and Mr. Vincent, who proposed to apply it in the construction of the dynamo-electric machines. On two occasions[12] they communicated to the Royal Society the results of experiments to show that the same exciting current would evoke a larger amount of magnetism in a given iron structure if that iron structure formed a closed magnetic circuit than if it were otherwise disposed.

In recent years the notion of the magnetic circuit has been vigorously taken up by the designers of dynamo machines, who indeed base the calculation of their designs upon this all-important principle. Having this, they need no laws of inverse squares of distances, no magnetic moments, none of the elaborate expressions for surface distribution of magnetism, none of the ancient paraphernalia of the last century. The simple law of the magnetic circuit and a knowledge of the properties of iron are practically all they need. About four years ago, much was done by Mr. Gisbert Kapp[13] and by Drs. J. and E. Hopkinson[14] in the application of these considerations to the design of dynamo machines, which previously had been a matter of empirical practice. To this end the formulæ of Professor Forbes[1] for calculating magnetic leakage, and the researches of Professors Ayrton and Perry[2] on magnetic shunts, contributed a not unimportant share. As the result of the advances made at that time, the subject of dynamo design was reduced to an exact science.

It is the aim and object of the present course of lectures to show how the same considerations which have been applied with such great success to the subject of the design of dynamo-electric machines may be applied to the study of the electro-magnet. The theory and practice of the design and construction of electro-magnets will thus be placed, once for all, upon a rational basis. Definite rules will be laid down for the guidance of the constructor, directing him as to the proper dimensions and form of iron to be chosen, and as to the proper size and amount of copper wire to be wound upon it in order to produce any desired result.

First, however, a historical account of the invention will be given, followed by a number of general considerations respecting the uses and forms of electro-magnets. These will be followed by a discussion of the magnetic properties of iron and steel and other materials. Some account being added of the methods used for determining the magnetic permeability of various brands of iron at different degrees of saturation.

Tabular information is given as to the results found by different observers. In connection with the magnetic properties of iron the phenomenon of magnetic hysteresis is also described and discussed. The principle of the magnetic circuit is then discussed with numerical examples, and a number of experimental data respecting the performance of electro-magnets are adduced, in particular those bearing upon the tractive power of electro-magnets. The law of traction between an electro-magnet and its armature is then laid down, followed by the rules for predetermining the iron cores and copper coils required to give any prescribed tractive force.

Then comes the extension of the calculation of the magnetic circuit to those cases where there is an air gap between the poles of the magnet and the armature, and where in consequence there is leakage of the magnetic lines from pole to pole. The rules for calculating the winding of the copper coils are stated, and the limiting relation between the magnetizing power of the coil and the heating effect of the current in it is explained. After this comes a detailed discussion of the special varieties of form that must be given to electro-magnets in order to adapt them to special services.

Those which are designed for maximum traction, for quickest action, for longest range, for greatest economy when used in continuous daily service, for working in series with constant current, for use in parallel at constant pressure, and those for use with alternate currents, are separately considered.

Lastly some account is given of the various forms of electromagnetic mechanism which have arisen in connection with the invention of the electromagnet. The plunger and coil is specially considered as constituting a species of electromagnet adapted for a long range of motion. Modes of mechanically securing long range for electromagnets, and of equalizing their pull over the range of motion of the armature, are also described. The analogies between sundry electro-mechanical movements and the corresponding pieces of ordinary mechanism are traced out. The course is concluded by a consideration of the various modes of preventing or minimizing the sparks which occur in the circuits in which electromagnets are used.

HISTORICAL SKETCH.

The effect which an electric current, flowing in a wire, can exercise upon a neighboring compass needle was discovered by Oersted in 1820.[3] This first announcement of the possession of magnetic properties by an electric current was followed speedily by the researches of Ampere,[4] Arago,[5] Davy,[6] and by the devices of several other experimenters, including De la Rive's[7] floating battery and coil, Schweigger's[8] multiplier, Cumming's[9] galvanometer, Faraday's[10] apparatus for rotation of a permanent magnet, Marsh's[11] vibrating pendulum, and Barlow's[12] rotating star wheel. But it was not until 1825 that the electromagnet was invented. Davy had, indeed, in 1821, surrounded with temporary coils of wire the steel needles upon which he was experimenting, and had shown that the flow of electricity around the coil could confer magnetic power upon the steel needles. But from this experiment it was a grand step forward to the discovery that a core of soft iron, surrounded by its own appropriate coil of copper, could be made to act not only as a powerful magnet, but as a magnet whose power could be turned on or off at will, could be augmented to any desired degree, and could be set into action and controlled from a practically unlimited distance.

The electromagnet, in the form which can first claim recognition for these qualities, was devised by William Sturgeon,[13] and is described by him in the paper which

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[1] Lectures delivered before the Society of Arts, London, 1890. From the Journal of the Society.

[1] "Camb. Phil. Trans.," April 2, 1821.

[2] "Phil. Mag.," series iii., vol. iii., p. 122.

[3] "Ann. of Electr.," xii., p. 217.

[4] "Pogg. Ann.," xxix., p. 462, 1833. See also "Pogg. Ann.," xliii., p. 517, 1838.

[5] "Dub. Elektromagnetismus" (ed. 1861), p. 401; and "Pogg. Ann.," xc., p. 440, 1853.

[6] De la Rive. "Treatise on Electricity" (Walker's translation), vol. i., p. 292.

[7] "Ann. of Electr.," iv., 59, 1839; v., 195, 1841; and "Scientific Papers," pp. 8, 34, 35, 36.

[8] "Experimental Researches," vol. iii., art. 3117, 3228, 3230, 3260, 3271, 3276, 3294, and 3361.

[9] "Phil. Mag.," series iv., vol. xlvi., August, 1873, "On Magnetic Permeability and the Maximum of Magnetism of Iron, Steel, and Nickel."

[10] "Proc. Royal Soc.," xxxiv., p. 445, December, 1882.

[11] "Phil. Mag.," series v., vol. xv., p. 205, March, 1883, "On Magneto Motive Force." Also ib., vol. xix., February, 1885, and "Proc. Roy. Soc.," No. 222, 1883. See also "Electrician," xiv., p. 291, February 14, 1885.

[12] "Proc. Roy. Soc.," xxix., p. 292, 1879, and xxx., p. 287, 1880. See "Electrical Review," viii., p. 134, 1880.

[13] "The Electrician," vols. xiv., xv., xvi., 1885-86. Also "Proc. Inst. Civil Engineers," lxxxiii., 1885-86, and "Journ. Soc. Telegr. Engineers," xv., 524, 1886.

[14] "Phil. Trans.," 1886, pt. i., p. 331, and "The Electrician," xviii., pp. 39, 63, 86, 1886.

[1] "Journ. Soc. Telegr. Engineers," xv., 555, 1886.

[2] "Journ. Soc. Telegr. Engineers," xv., 530, 1886.

[3] See Thomson's "Annals of Philosophy," Oct., 1820.

[4] "Ann. de Chim. et de Physique," xv., 59 and 170, 1820.

[5] Ib., xv., 93, 1820.

[6] "Phil. Trans.," 1821.

[7] "Bibliotheque Universelle," March, 1821.

[8] Ib.

[9] "Camb. Phil. Trans.," 1821.

[10] "Quarterly Journal of Science," Sept., 1821.

[11] "Barlow's Magnetic Attractions," second edition, 1823.

[12] Ib.

[13] William Sturgeon, the inventor of the electromagnet, was born at Whittington, in Lancashire, in 1783. Apprenticed as a boy to the trade of a shoemaker, at the age of nineteen he joined the Westmoreland militia, and two years later enlisted in the Royal Artillery, thus gaining the chance of learning something of science, and having leisure in which to pursue his absorbing passion for chemical and physical experiments. He was forty-two years of age when he made his great, though at the time unrecognized, invention. At the date of his researches in electromagnetism he was resident at 8 Artillery place, Woolwich, at which place he was the associate of Marsh, and was intimate with Barlow, Christie, and Gregory, who interested themselves in his work. In 1835 he presented a paper to the Royal Society containing descriptions, *inter alia*, of a magneto-electric machine with longitudinally wound armature, and with a commutator consisting of half disks of metal. For some reason this paper was not admitted

he contributed to the Proceedings of the Society of Arts, in 1825, accompanying a set of improved apparatus for electromagnetic experiments.[1] The Society of Arts rewarded Sturgeon's labors by awarding him the silver medal of the society and a premium of thirty guineas. Among this set of apparatus are two electromagnets, one of horseshoe shape (Figs. 1 and 2) and

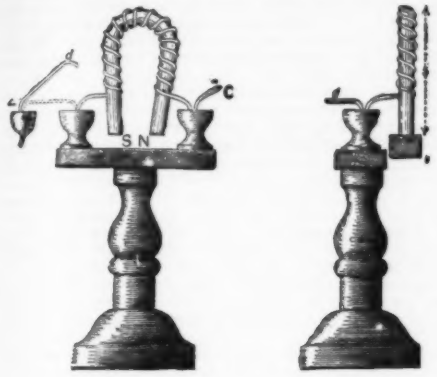

FIG. 1. FIG. 2.

STURGEON'S FIRST ELECTROMAGNET.

one a straight bar (Fig. 3). It will be seen that the former figures represent a electromagnet consisting of a bent iron rod about one foot long and half inch in diameter, varnished over and then coiled with a single left-handed spiral of stout, uncovered copper wire of 18 turns. This coil was found appropriate to the particular battery which Sturgeon preferred, namely, a single cell containing a spirally enrolled pair of zinc and copper plates of large area (about 130 square inches) immersed in acid; which cell, having small internal resistance, would yield a large quantity of current when connected to a circuit of small resistance. The ends of

FIG. 3.—STURGEON'S STRAIGHT BAR ELECTROMAGNET.

the copper wire were brought out sideways and bent down so as to dip into two deep connecting cups, marked Z and C, fixed upon a wooden stand. These cups, which were of wood, served as supports to hold up the electromagnet, and having mercury in them served also to make good electrical connection.

In Fig. 2, the magnet is seen sideways, supporting a bar of iron, *y*. The circuit was completed to the battery through a connecting wire, *d*, which could be lifted out of the cup, Z, so breaking circuit when desired, and allowing the weight to drop. Sturgeon added in his explanatory remarks that the poles, N and S, of the magnet will be reversed if you wrap the copper wire about the rod as a right-handed screw, instead of a left-handed one, or, more simply, by reversing the connections with the battery, by causing the wire that dips into the Z cup to dip into the C cup, and *vice versa*. This electromagnet was capable of supporting nine pounds when thus excited.

Fig. 3 shows another arrangement to fit on the same stand. This arrangement communicates magnetism to hardened steel bars, as soon as they are put in, and renders soft iron within it magnetic during the time of action; it only differs from Figs. 1 and 2 in being straight, and thereby allows the steel or iron bars to slide in and out.

For this piece of apparatus and other adjuncts accompanying it, all of which are described in the society's "Transactions" for 1825, Sturgeon, as already stated, was awarded the society's silver medal and a premium of thirty guineas. The apparatus was deposited in the museum of the society, which, therefore, might be supposed to be the proud possessor of the first electromagnet ever constructed. Alas for the vanity of human affairs! the society's museum of apparatus has long been dispersed, this priceless relic having been either made over to the now defunct Patent-office Museum, or otherwise lost sight of.

Sturgeon's first electromagnet, the core of which weighed about 7 oz., was able to sustain a load of 9 lb., or about 20 times its own weight. At the time it was considered a truly remarkable performance. Its single layer of stout copper wire was well adapted to the battery employed, a single cell of Sturgeon's own particular construction, having a surface of 130 sq. in., and therefore of small internal resistance. Subsequently in the hands of Joule, the same electromagnet sustained a load of 50 lb., or about 114 times its own weight. Writing in 1832 about his apparatus of 1825, Sturgeon used the following magniloquent language:

"When first I showed that the magnetic energies of a galvanic conducting wire are more conspicuously exhibited by exercising them on soft iron than on hard steel, my experiments were limited to small masses—generally to a few inches of rod iron about half an inch in diameter. Some of those pieces were employed while straight and others were bent into the form of a horseshoe magnet, each piece being encompassed by a spiral conductor of copper wire. The magnetic energies developed by these simple arrangements are of a very distinguished and exalted character, as is conspicuously manifested by the suspension of a considerable weight at the poles during the period of excitation by the electric influence.

"An unparalleled transiliency of magnetic action is also displayed in soft iron, by an instantaneous transition from a state of total inactivity to that of vigorous polarity, and also by a simultaneous reciprocity of polarity in the extremities of the bar—versatilities in this branch of physics for the display of which soft iron is pre-eminently qualified, and which, by the agency of electricity, become demonstrable with the celerity of thought, and illustrated by experiments the most splendid in magnetics. It is, moreover, abundantly manifested by ample experiments that galvanic electricity exercises a superlative degree of excitation on the latent magnetism of soft iron, and calls for its recondite powers with astonishing promptitude, to an intensity of action far surpassing anything which can be accomplished by any known application of the most vigorous permanent magnet, or by any other mode of experimenting hitherto discovered. It has been observed, however, by experimenting on different pieces selected from various sources, that, notwithstanding the greatest care be observed in preparing them of a uniform figure and dimensions, there appears a considerable difference in the susceptibility which they individually possess of developing the magnet powers, much of which depends upon the manner of treatment at the forge, as well as upon the natural character of the iron itself.[1]

"The superlative intensity of electromagnets, and the facility and promptitude with which their energies can be brought into play, are qualifications admirably adapted for their introduction into a variety of arrangements in which powerful magnets so essentially operate, and perform a distinguished part in the production of electromagnetic rotations; while the versatilities of polarity of which they are susceptible are eminently calculated to give a pleasing diversity in the exhibition of that highly interesting class of phenomena, and lead to the production of others inimitable by any other means."[2]

Sturgeon's further work during the next three years is best described in his own words:

"It does not appear that any very extensive experiments were attempted to improve the lifting power of electromagnets, from the time that my experiments were published in the 'Transactions of the Society of Arts,' etc., for 1825, till the latter part of 1828. Mr. Watkins, philosophical instrument maker, Charing-cross, had, however, made them of much larger size than any which I had employed, but I am not aware to what extent he pursued the experiment.

"In the year 1828, Professor Moll, of Utrecht, being on a visit to London, purchased of Mr. Watkins an electromagnet weighing about 5 lb.—at that time I believe the largest which had been made. It was of round iron, about one inch in diameter, and furnished with a single copper wire twisted round it eighty-three times. When this magnet was excited by a large galvanic surface, it supported about 75 lb. Professor Moll afterward prepared another electromagnet, which, when bent, was 12½ inches high, 2½ inches in diameter, and weighed about 26 lb., prepared like the former with a single spiral conducting wire. With an acting galvanic surface of 11 square feet, this magnet would support 154 lb., but would not lift an anvil which weighed 200 lb.

"The largest electromagnet which I have yet [1832] exhibited in my lectures weighs about 16 lb. It is formed of a small bar of soft iron, 1½ inch across each side; the cross piece, which joins the poles, is from the same rod of iron, and about 3¾ inches long. Twenty separate strands of copper wire, each strand about fifty feet in length, are coiled round the iron, one above another, from pole to pole, and separated from each other by intervening cases of silk; the first coil is only the thickness of one ply of silk from the iron, the twentieth or outermost, about half an inch from it. By this means the wires are completely insulated from each other without the trouble of covering them with thread or varnish. The ends of wire project about two feet for the convenience of connection. With one of my small cylindrical batteries, exposing about 150 square inches of total surface, this electromagnet supports 400 lb. I have tried it with a larger battery, but its energies do not seem to be so materially exalted as might have been expected by increasing the extent of galvanic surface. Much depends upon a proper acid solution; good nitric or nitrous acid, with about six or eight times its quantity of water, answers very well. With a new battery of the above dimensions and a strong solution of salt and water, at a temperature of 190° Fahr., the electromagnet supported between seventy and eighty pounds, when the first seventeen coils only were in the circuit. With the three exterior coils alone in the circuit, it would just support the lifter, or cross piece. When the temperature of the solution was between 40° and 50°, the magnetic force excited was comparatively very feeble. With the innermost coil alone and a strong acid solution this electromagnet supports about 100 lb., with the four outermost wires about 250 lb. It improves in power with every additional coil until about the twelfth, but not perceptibly any further. Therefore the remaining eight coils appear to be useless, although the last three, independently of the innermost seventeen, and at the distance of half an inch from the iron, produce in it a lifting power of 75 lb.

"Mr. Marsh has fitted up a bar of iron much larger than mine, with a similar distribution of the conducting wires to that devised and so successfully employed by Professor Henry. Mr. Marsh's electromagnet will support about 560 lb. when excited by a galvanic battery similar to mine. These two, I believe, are the most powerful electromagnets yet produced in this country.

"A small electromagnet, which I also employ on the lecture table, and the manner of its suspension is represented by Fig. 4. The magnet is of cylindric rod iron,

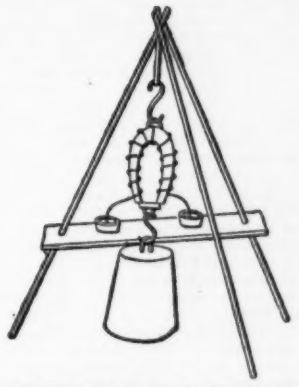

FIG. 4.—STURGEON'S LECTURE TABLE ELECTROMAGNET.

and weighs four ounces; its poles are about a quarter of an inch asunder. It is furnished with six coils of wire in the same manner as the large electromagnet before described, and will support upward of 50 lb.

"I find a triangular gin very convenient for the suspension of the magnet in these experiments. A stage of thin board, supporting two wooden dishes, fastened at a proper height to two of the legs of the gin. Mercury is placed in these vessels, and the dependent amalgamated extremities of the conducting wires dip into it—one into each portion.

"The vessels are sufficiently wide to admit of considerable motion of the wires in the mercury without interrupting the contact, which is sometimes occasioned by the swinging of the magnet and attached weight. The circuit is completed by other wires, which connect the battery with these two portions of mercury. When the weight is supported as in the figure, if an interruption be made by removing either of the connecting wires, the weight instantaneously drops on the table. The large magnet I suspend in the same way on a larger gin; the weights which it supports are placed one after another on a square board, suspended by means of a cord at each corner from a hook in the cross piece, which joins the poles of the magnet.

"With a new battery, and a solution of salt and water, at a temperature of 190° Fah., the small electromagnet, Fig. 3, supports 16 lb."

In 1840, after Sturgeon had removed to Manchester, where he assumed the management of the "Victoria Gallery of Practical Science," he continued his work, and in the seventh memoir in his series of researches he wrote as follows:

"The electromagnet belonging to this institution is made of a cylindrical bar of soft iron, bent into the form of a horseshoe magnet, having the two branches parallel to each other, and at the distance of 4·5 inches. The diameter of the iron is 2·75 inches, it is 18 inches long when bent. It is surrounded by fourteen coils of copper wire, seven on each branch. The wire which constitutes the coils is 1-12th of an inch diameter, and in each coil there are about seventy feet of wire. They are united in the usual way with branch wires, for the purpose of conducting the currents from the battery. The magnet was made by Mr. Nesbit. . . . The greatest weight sustained by the magnet in these experiments is 12¾ cwt., or 1,386 lb., which was accomplished by sixteen pairs of plates, in four groups of four pairs in series each. The lifting power by nineteen pairs in series was considerably less than by ten pairs in series; and but very little greater than that given by one cell or one pair only. This is somewhat remarkable, and shows how easily we may be led to waste the magnetic powers of batteries by an injudicious arrangement of its elements."[1]

At the date of Sturgeon's work the laws governing the flow of electric currents in wires were still obscure. Ohm's epoch-making enunciation of the law of the electric circuit appeared in "Poggendorff's Annalen" in the very year of Sturgeon's discovery, 1825, though his complete book appeared only in 1827, and his work, translated by Dr. Francis into English, only appeared (in Taylor's "Scientific Memoirs," vol. ii.) in 1841. Without the guidance of Ohm's law it was not strange that even the most able experimenters should not understand the relations between battery and circuit which would give them the best effects. These had to be found by the painful method of trial and failure. Pre-eminent among those who tried was Professor Joseph Henry, then of the Albany Institute in New York, later of Princeton, New Jersey, who succeeded in effecting an important improvement. In 1828, led on by a study of the "multiplier" (or galvanometer), he proposed to apply to electromagnetic apparatus the device of winding them with a spiral coil of wire "closely turned on itself," the wire being of copper from 1-40th to 1-25th of an inch in diameter, covered with silk. In 1831 he thus describes[2] the results of his experiments:

"A round piece of iron, about ¼ of an inch in diameter, was bent into the usual form of a horseshoe, and instead of loosely coiling around it a few feet of wire, as is usually described, it was tightly wound with 35

to the "Philosophical Transactions." He afterward printed it in full, without alteration in, his volume of Scientific Researches, published by subscription in 1850. From 1836 to 1843 he conducted the "Annals of Electricity." He had now removed to Manchester, where he lectured on electricity at the Royal Victoria Gallery. He died at Prestwich, near Manchester, in 1850. There is a tablet to his memory in the church at Kirkby Lonsdale, from which town the village of Whittington is distant about two miles. A portrait of Sturgeon in oils, and said to be an excellent likeness, is believed still to be in existence. But all inquiries as to its whereabout have proved unavailing. At the present moment, so far as I am aware, the scientific world is absolutely without a portrait of the inventor of the electromagnet.

[1] "Trans. Society of Arts," 1825, xliii., p. 38.

[1] "I have made a number of experiments on small pieces, from the results of which it appears that much hammering is highly detrimental to the development of magnetism in soft iron, whether the exciting cause be galvanic or any other. And although good annealing is always essential, and facilitates to a considerable extent the display of polarity, that process is very far from restoring to the iron that degree of susceptibility which it frequently loses by the operation of the hammer. Cylindric rod iron of small dimensions may very easily be bent into the required form, without any hammering whatever; and I have found that small electromagnets made in this way display the magnetic powers in a very exalted degree."

[2] Sturgeon's "Scientific Researches," p. 113.

[1] Sturgeon's "Scientific Researches," p. 188.

[2] Silliman's "American Journal of Science," January, 1831, xix., p. 400.

feet of wire, covered with silk, so as to form about 400 turns; a pair of small galvanic plates, which could be dipped into a tumbler of diluted acid, was soldered to the ends of the wire, and the whole mounted on a stand. With these small plates the horseshoe became much more powerfully magnetic than another of the same size, and wound in the same manner, by the application of a battery composed of 28 plates of copper and zinc, each eight inches square. Another convenient form of this apparatus was contrived by winding a straight bar of iron, nine inches long, with 35 feet of wire, and supporting it horizontally on a small cup of copper containing a cylinder of zinc; when this cup, which served the double purpose of a stand and the galvanic element, was filled with dilute acid, the bar became a portable electromagnet. These articles were exhibited to the Institute in March, 1829. The idea afterward occurred to me that a sufficient quantity of galvanism was furnished by the two small plates to develop, by means of the coil, a much greater magnetic power in a larger piece of iron. To test this, a cylindrical bar of iron one-half an inch in diameter, and about ten inches long, was bent into the shape of a horseshoe, and wound with 30 feet of wire. With a pair of plates containing only 2½ square inches of zinc, it lifted 15 lb. avoirdupois. At the same time, a very material improvement in the formation of the coil suggested itself to me on reading a more detailed account of Professor Schweigger's galvanometer, and which was also tested with complete success upon the same horseshoe; it consisted in using several strands of wire, each covered with silk, instead of one. Agreeably to this construction, a second wire, of the same length as the first, was wound over it, and the ends soldered to the zinc and copper in such a manner that the galvanic current might circulate in the same direction in both, or, in other words, that the two wires might act as one. The effect by this addition was doubled, as the horseshoe, with the same plates before used, now supported 28 lb.

"With a pair of plates 4 inches by 6 inches, it lifted 39 lb., or more than fifty times its own weight.

"These experiments conclusively proved that a great development of magnetism could be effected by a very small galvanic element, and also that the power of the coil was materially increased by multiplying the number of wires without increasing the number of each."[1]

Not content with these results, Professor Henry pushed forward on the line he had thus struck out. He was keenly desirous to ascertain how large a magnetic force he could produce when using only currents of such a degree of smallness as could be transmitted through the comparatively thin copper wires such as bell hangers use. During the year 1830 he made great progress in this direction, as the following extracts show:

"In order to determine to what extent the coil could be applied in developing magnetism in soft iron, and also to ascertain, if possible, the most proper length of the wires to be used, a series of experiments was instituted jointly by Dr. Philip Ten Eyck and myself. For this purpose 1,060 feet (a little more that one-fifth of a mile) of copper wire of the kind called bell wire, 0·045 of an inch in diameter, was stretched several times across the large room of the academy.

"*Experiment* 1.—A galvanic current from a single pair of plates of copper and zinc two inches square was passed through the whole length of the wire, and the effect on a galvanometer noted. From the mean of several observations, the deflection of the needle was 15°.

"*Experiment* 2.—A current from the same plates was passed through half the above length, or 530 feet of wire; the deflection in this instance was 21°.

"By a reference to a trigonometrical table, it will be seen that the natural tangents of 15° and 21° are very nearly in the ratio of the square roots of 1 and 2, or of the relative lengths of the wires in these two experiments.

"The length of the wire forming the galvanometer may be neglected, as it was only 8 feet long.

"*Experiment* 3.—The galvanometer was now removed, and the whole length of the wire attached to the ends of the wire of a small soft iron horseshoe a quarter of an inch in diameter, and wound with about 8 feet of copper wire with a galvanic current from the plates used in experiments 1 and 2. The magnetism was scarcely observable in the horseshoe.

"*Experiment* 4.—The small plates were removed, and a battery composed of a piece of zinc plate 4 inches by 7 inches, surrounded with copper, was substituted. When this was attached immediately to the ends of the 8 feet of wire wound round the horseshoe, the weight lifted was 4½ lb. When the current was passed through the whole length of wire (1,060 feet), it lifted about half an ounce.

"*Experiment* 5.—The current was passed through half the length of wire (530 feet) with the same battery. It then lifted two ounces.

"*Experiment* 6.—Two wires of the same length as in the last experiment were used, so as to form two strands from the zinc and copper of the battery. In this case the weight lifted was four ounces.

"*Experiment* 7.—The whole length of the wire was attached to a small trough on Mr. Cruikshank's plan, containing 25 double plates, and presenting exactly the same extent of zinc surface to the action of the acid as the battery used in the last experiment. The weight lifted in this case was 8 oz. When the intervening wire was removed, and the trough attached directly to the ends of the wire surrounding the horseshoe, it lifted only 7 oz. . . . . .

"It is possible that the different states of the trough, with respect to dryness, may have exerted some influence on this remarkable result, but that the effect of a current from a trough, if not increased, is but slightly diminished in passing through a long wire is certain.

. . . . . .

"But be this as it may, the fact that the magnetic action of a current from a trough is, at least, not sensibly diminished by passing through a long wire is directly applicable to Mr. Barlow's project of forming an electro-magnetic telegraph, and it is also of material consequence in the construction of the galvanic coil. From these experiments it is evident that in forming the coil we may either use one very long wire or several shorter ones, as the circumstances may require. In the first case our galvanic combinations must consist of a number of plates, so as to give 'projectile force.' In the second it must be formed of a single pair.

"In order to test on a large scale the truth of these preliminary results, a bar of soft iron, 2 inches square and 20 inches long, was bent into the form of a horseshoe, 9½ inches high. The sharp edges of the bar were first a little rounded by the hammer. It weighed 21 lb. A piece of iron from the same bar, weighing 7 lb., was filed perfectly flat on one surface, for an armature or lifter. The extremities of the legs of the horseshoe were also truly ground to the surface of the armature. Around this horseshoe 540 feet of copper bell wire were wound in 9 coils of 60 feet each. These coils were not

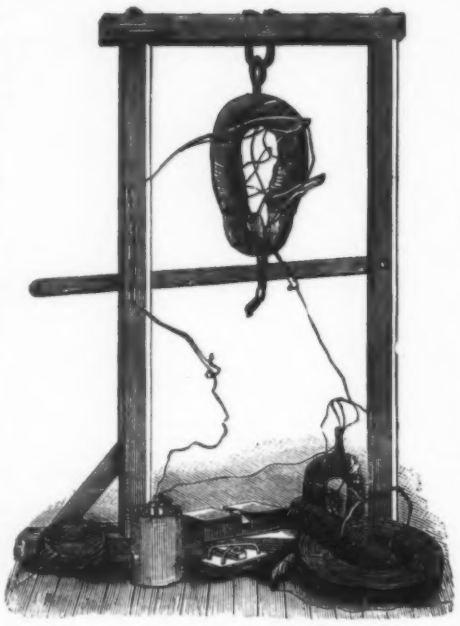

FIG. 5.—HENRY'S ELECTROMAGNET.

This figure, copied from the SCIENTIFIC AMERICAN, December 11, 1880, represents Henry's electro-magnet, still preserved in Princeton College. The other apparatus at the foot, including a current reverser, and the ribbon coil used in the famous experiments on secondary and tertiary currents, were mostly constructed by Henry's own hands.

continued around the whole length of the bar, but each strand of wire, according to the principle before mentioned, occupied about two inches and was coiled several times backward and forward over itself. The several ends of the wires were left projecting and all numbered, so that the first and last end of each strand might be readily distinguished. In this manner we formed an experimental magnet on a large scale, with which several combinations of wire could be made by merely uniting the different projecting ends. Thus, if the second end of the first wire be soldered to the first end of the second wire, and so on through all the series, the whole will form a continued coil of one long wire.

"By soldering different ends the whole may be formed into a double coil of half the length, or into a triple coil of one-third the length, etc. The horseshoe was suspended in a strong rectangular wooden frame, three feet nine inches high and twenty inches wide, an iron bar was fixed below the magnet, so as to act as a lever of the second order. The different weights supported were estimated by a sliding weight in the same manner as with a common steelyard (see sketch). In the experiments immediately following (all weights being avoirdupois) a small single battery was used, consisting of two concentric copper cylinders with zinc between them. The whole amount of zinc surface exposed to the acid from both sides of the zinc was 2-5ths of a square foot. The battery required only half a pint of dilute acid for its submersion.

"*Experiment* 8.—Each wire of the horseshoe was soldered to the battery in succession, one at a time. The magnetism developed by each was just sufficient to support the weight of the armature, weighing 7 lb.

"*Experiment* 9.—Two wires, one on each side of the arch of the horseshoe, were attached. The weight lifted was 145 lb.

"*Experiment* 10.—With two wires, one from each extremity of the legs, the weight lifted was 200 lb.

"*Experiment* 11.—With three wires, one from each extremity of the legs, and one from the middle of the arch, the weight supported was 300 lb.

"*Experiment* 12.—With four wires, two from each extremity, the weight lifted was 500 lb. and the armature. When the acid was removed from the zinc, the magnet continued to support for a few minutes 130 lb.

"*Experiment* 13.—With six wires the weight supported was 570 lb. In all these experiments the wires were soldered to the galvanic element. The convection in no case was formed with mercury.

"*Experiment* 14.—When all the wires (nine in number) were attached, *the maximum weight lifted was 950 lb.*, and this astonishing result, it must be remembered, was produced by a battery containing only 2-5ths of a square foot of zinc surface, and requiring only a half a pint of dilute acid for its submersion.

"*Experiment* 15.—A small battery formed with a plate of zinc 12 inches long and 6 inches wide, and surrounded by copper, was substituted for the galvanic elements used in the last experiment. The weight lifted in this case was 750 lb.

"*Experiment* 16.—In order to ascertain the effect of a very small galvanic element on this large quantity of iron, a pair of plates, exactly one inch square, was attached to all the wires. The weight lifted was 85 lb.

"The following experiments were made with wires of different lengths on the same horseshoe:

"*Experiment* 17.—With six wires, each 30 feet long, attached to the galvanic element, the weight lifted was 375 lb.

"*Experiment* 18.—The same wires used in last experiment were united so as to form three coils of 60 feet each. The weight supported was 290 lb. This result agrees nearly with experiment 11, though the same individual wires were not used. From this it appears that six short wires are more powerful than three of double the length.

"*Experiment* 19.—The wires used in experiment 10, but united so as to form a single coil of 120 feet of wire, lifted 60 lb., while in experiment 10 the weight lifted was 200 lb. This is a confirmation of the result in the last experiment. . . . . .

"In these experiments a fact was observed which appears somewhat surprising. When the large battery was attached, and the armature touching both poles of the magnet, it was capable of supporting more than 700 lb., but when only one pole is in contact it did not support more than 5 or 6 lb., and in this case we never succeeded in making it lift the armature (weighing 7 lb.) This fact may, perhaps, be common to all large magnets, but we have never seen the circumstance noticed of so great a difference between a single pole and both. . . . . .

"A series of experiments was separately instituted by Dr. Ten Eyck, in order to determine the maximum development of magnetism in a small quantity of soft iron.

"Most of the results given in this paper were witnessed by Dr. L. C. Beck, and to this gentleman we are indebted for several suggestions, and particularly that of substituting cotton well waxed for silk thread, which in these investigations became a very considerable item of expense. He also made a number of experiments with iron bonnet wires, which, being found in commerce already wound, might possibly be substituted in place of copper. The result was that with very short wire the effect was nearly the same as with copper, but in coils of long wire with a small galvanic element it was not found to answer. Dr. Beck also constructed a horseshoe of round iron 1 inch in diameter, with four coils on the plan before described. With one wire it lifted 30 lb., with two wires 60 lb., with three wires 85 lb., and with four wires 112 lb. While we were engaged in these investigations, the last number of the Edinburgh *Journal of Science* was received, containing Prof. Moll's paper on 'Electro-Magnetism.' Some of his results are in a degree similar to those here described. His object, however, was different, it being only to induce strong magnetism on soft iron with a powerful galvanic battery. The principal object in these experiments was to produce the greatest magnetic force with the smallest quantity of galvanism. The only effect Prof. Moll's paper has had over these investigations has been to hasten their publication. The principle on which they were instituted was known to us nearly two years since, and at that time exhibited to the Albany Institute."[1]

In the next number of *Silliman's Journal* (April, 1831), Professor Henry gave "an account of a large electromagnet, made for the laboratory of Yale College." The core of the armature weighed 59½ lb., it was forged under Henry's own direction, and wound by Dr. Ten Eyck. This magnet, wound with 26 strands of copper bell-wire to total length of 728 feet, and excited by two cells which exposed nearly 4¼ square feet of surface, readily supported on its armature, which weighed 23 lb., a load of 2,063 lb.

Writing in 1867 of his earlier experiments, Henry speaks[2] thus of his ideas respecting the use of additional coils on the magnet and the increase of battery power:

"To test these principles on a larger scale, the experimental magnet was constructed, which is shown in Fig. 6. In this a number of compound helices was

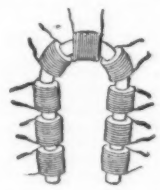

FIG. 6.—HENRY'S EXPERIMENTAL ELECTROMAGNET.

placed on the same bar, their ends left projecting, and so numbered that they could all be united into one long helix, or variously combined in sets of lesser length.

"From a series of experiments with this and other magnets, it was proved that in order to produce the greatest amount of magnetism from a battery of a single cup, a number of helices is required; but when a compound battery is used, then one long wire must be employed, making many turns around the iron, the length of wire and consequently the number of turns being commensurate with the projectile power of the battery.

"In describing the results of my experiments the terms 'intensity' and 'quantity' magnets were introduced to avoid circumlocution, and were intended to be used merely in a technical sense. By the intensity magnet I designated a piece of soft iron, so surrounded with wire that its magnetic power could be called into operation by an intensity battery; and by a quantity magnet, a piece of iron so surrounded by a number of separate coils that its magnetism could be fully developed by a quantity battery.

"I was the first to point out this connection of the two kinds of the battery with the two forms of the magnet, in my paper in *Silliman's Journal*, January, 1831, and clearly to state that when magnetism was to be developed by means of a compound battery one long coil must be employed, and when the maximum effect was to be produced by a single battery a number of single strands should be used. . . . Neither the electromagnet of Sturgeon nor any electromagnet ever made previous to my investigations was applicable to transmitting power to a distance. . . . The electromagnet made by Sturgeon, and copied by Dana, of New York, was an imperfect quantity magnet, the

[1] "Scientific Writings of Joseph Henry," p. 39.

[1] Scientific Writings of Joseph Henry, p. 49.

[2] Statement in Relation to the History of the Electromagnetic Telegraph: from the Smithsonian Annual Report for 1857, p. 99.

feeble power of which was developed by a single battery."

Finally, Henry[1] sums up his own position as follows:

"1. Previous to my investigations the means of developing magnetism in soft iron were imperfectly understood, and the electromagnet which then existed was inapplicable to transmissions of power to a distance.

"2. I was the first to prove by actual experiment that in order to develop magnetic power at a distance, a galvanic battery of 'intensity' must be employed to project the current through the long conductor, and that a magnet surrounded by many turns of one long wire must be used to receive this current.

"3. I was the first to actually magnetize a piece of iron at a distance, and to call attention to the fact of the applicability of my experiments to the telegraph.

"4. I was the first to actually sound a bell at a distance by means of the electromagnet.

"5. The principles I had developed were applied by Dr. Gale to render Morse's machine effective at a distance."

Though Henry's researches were published in 1831, they were for some years almost unknown in Europe. Until April, 1837, when Henry himself visited Wheatstone at his laboratory, at King's College, the latter did not know how to construct an electromagnet that could be worked through a long wire circuit. Cooke, who became the coadjutor of Wheatstone, had originally come to him to consult him,[2] in February, 1837, about his telegraph and alarm, the electromagnets of which, though they worked well on short circuits, refused to work when placed in circuit with even a single mile of wire. Wheatstone's own account[3] of the matter is extremely explicit: "Relying on my former experience, I at once told Mr. Cooke that his plan would not and could not act as a telegraph, because sufficient attractive power could not be imparted to an electromagnet interposed in a long circuit; and to convince him of the truth of this assertion, I invited him to King's College to see the repetition of the experiments on which my conclusion was founded. He came, and after seeing a variety of voltaic magnets, which, even with powerful batteries, exhibited only slight adhesive attraction, he expressed his disappointment."

After Henry's visit to Wheatstone, the latter altered his tone. He had been using, *faute de mieux*, relay circuits to work the electromagnets of his alarum in a short circuit with a local battery. "These short circuits," he writes, "have lost nearly all their importance, and are scarcely worth contending about since *my discovery*" (the italics are our own) "that electromagnets may be so constructed as to produce the required effect by means of the direct current, even in very long circuits."[4]

(To be continued.)

PRODUCTION OF STEEL IN THE UNITED STATES.

By Dr. WILLIAM M. SWEET.

THE total production of steel in the United States in the form of ingots or direct castings during the year ended June 30, 1890, amounted to 4,466,926 tons of 2,000 pounds, as compared with 1,145,711 tons produced during the year ended May 31, 1880; an increase of 3,321,215 tons or 290 per cent.

The following table gives the production of the various kinds of steel in the form of ingots or direct castings in 1880 and 1890. The statistics for 1880 are for the census year ended May 31, 1880, but for 1890 they cover the fiscal year ended June 30, 1890. A few steel works produce blister, cemented and other miscellaneous steel, but the quantity made annually is very small, and the statistics thereof for 1880 and 1890 are not included in the table below:

Kinds of Steel. (Ingots or direct castings.)	Tons of 2,000 pounds. Year ended May 31, 1880.	Year ended June 30, 1890.
Bessemer steel	985,208	3,788,572
Open hearth steel	84,302	504,351
Crucible steel	76,201	85,536
Clapp-Griffiths steel	.....	83,963
Robert-Bessemer steel	.....	4,504
Total	1,145,711	4,466,926

During 1880 fourteen States contained steel-making establishments, and steel was produced in that year in each of these States except Rhode Island and Maryland. In 1890 steel works were located in nineteen States, and steel was made in that year in each of these States except Kentucky, Missouri, and Virginia.

Pennsylvania continues to occupy the position of the leading producer of steel in the United States, producing 57 per cent. of the total production in 1880 and 63 per cent. in 1890. Illinois was second in rank in both years, and Ohio was third. From 1880 to 1890 the increase in production in Pennsylvania was 324 per cent., in Illinois 241 per cent., and in Ohio 314 per cent. Since 1880 the manufacture of steel has been abandoned in two States, viz., Rhode Island, and Vermont, and seven States have engaged in its production, viz., Alabama, California, Colorado, Indiana, Michigan, Virginia, and West Virginia.

The following table gives, in tons of 2,000 pounds, the total production, by States, of Bessemer, Clapp-Griffiths, Robert-Bessemer, open-hearth, and crucible steel, in the form of ingots or direct castings, during 1880 and 1890, with the number of completed steel works at the close of each year, the relative rank of each State, and the percentage of the total production.

BESSEMER STEEL.

The production of Bessemer steel ingots or direct castings in the United States during 1890, including steel made by the Clapp-Griffiths and Robert-Bessemer processes, amounted to 3,877,039 tons of 2,000 pounds, an increase of 294 per cent. over the production of 985,208 tons in 1880. In 1880 there were 11 completed works in this country for the production of Bessemer steel ingots or direct castings, which were located in Illinois, Missouri, New York, Ohio, and Pennsylvania, while at the close of 1890 the number of establishments containing Bessemer converters, including the works prepared to manufacture Clapp-Griffiths and Robert-Bessemer steel, had increased to 53, located in Colorado, Illinois, Indiana, Massachusetts, Michigan, Missouri, New York, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia.

Of the production of 985,208 tons of Bessemer steel ingots or direct castings in 1880, Pennsylvania produced 56 per cent., Illinois 26 per cent., and New York and Ohio each over 8 per cent. Of the production of 3,877,039 tons of Bessemer steel ingots or direct castings in 1890, including that made by the Clapp Griffiths and Robert-Bessemer steel works, Pennsylvania produced 59 per cent., Illinois 22 per cent., Ohio nearly 10 per cent., West Virginia 5 per cent., New York over 2 per cent., and Colorado, Massachusetts, and Michigan each less than 1 per cent.

The Clapp-Griffiths and Robert-Bessemer processes were introduced into the United States during the past decade, the former from Great Britain in 1884 and the latter from France in 1888. Both processes are modications of the ordinary Bessemer method, but the converters employed are nearly all of small capacity. The first steel made in this country by the Clapp-Griffiths process was produced at Pittsburg, Pennsylvania, March 25, 1884. During 1890 seven works contained converters for the production of steel by this process, five of which were in operation in that year, producing 83,963 tons of steel ingots or direct castings. No new plants have been erected since 1887, and none are now under construction. The first steel produced in this country by the Robert-Bessemer process was made at experimental works at Springfield, Ohio, in September, 1888.

During the year 1890 there were six completed works containing converters for the production of steel by this process, and one plant was in course of erection. The process may be said to be still in an experimental stage, but the results that have so far been obtained by its use are reported to be encouraging. During 1890 there were 4,504 tons of Robert-Bessemer steel produced in this country, principally in the form of castings.

The following table gives in tons of 2,000 pounds the production of Bessemer steel ingots or direct castings (the figures for 1890 including the quantity of steel made by the Clapp-Griffiths and Robert-Bessemer processes) and Bessemer steel rails in the United States in 1880 and 1890:

States.	Bessemer Steel Ingots or Direct Castings. (Including Clapp-Griffiths and Robert-Bessemer steel.) Year ended May 31, 1880.	Year ended June 30, 1890.	Bessemer Steel Rails. Year ended May 31, 1880.	Year ended June 30, 1890.
California	....	....	....	5,654
Colorado	....	17,952	....	14,286
Illinois	253,514	867,505	201,186	622,200
Indiana	....	....	....	....
Massachusetts	....	15,753	....	....
Michigan	....	3,600	....	....
Missouri	8,409	....	5,100	....
New York	84,160	105,402	57,870	....
Ohio	82,811	385,576	66,480	17,335
Pennsylvania	556,314	2,297,729	409,339	1,377,119
Tennessee	....	....	....	....
Virginia	....	....	....	....
Vermont	....	....	1,500	....
West Virginia	....	183,225	....	....
Total	985,208	3,877,039	741,475	2,036,654

The remarkable growth that has taken place in the Bessemer steel industry of this country during the past ten years is well shown by the above figures. The increase in the number of establishments producing Bessemer steel has been the result almost entirely of the demand for steel in forms other than rails. All of the eleven Bessemer steel plants that were completed in 1880 had been built to manufacture steel for rails, many of them being added to previously existing iron rail mills. Of the fifty-three Bessemer steel plants at the close of 1890, only fourteen made steel rails during that year, and of the total quantity of rails produced over 90 per cent. was made by ten of these works. Thus, while the production of steel rails has nearly trebled in amount since 1880, the number of establishments engaged in their manufacture has shown but little change in the ten years, although many of these works have greatly increased in size and efficiency. The competition in the manufacture of Bessemer steel rails has compelled many of the rail mills to convert a large part of the steel produced by them into forms other than rails, the production of rails to any considerable extent at the present time being possible only in works favorably located for the supply of cheap raw materials and operated under the latest and most improved methods of manufacture. Included in the total production of Bessemer steel rails during 1890 were 65,273 tons rolled in iron rolling mills from purchased Bessemer steel blooms.

While the demand for steel rails has shown a remarkable growth since 1880, thereby forcing a practical discontinuance of the manufacture of iron rails, there has also been a rapidly increasing use of steel for nails, bars, rods, wire, and other miscellaneous forms. The growth of the Bessemer steel industry in this direction is clearly shown in the number of plants that have been added to iron rolling mills during the past ten years for the purpose of manufacturing steel in forms other than rails. The increased quantity of Bessemer steel manufactured in these miscellaneous forms is approximately shown by a comparison of the ingots and rails produced, over 75 per cent. of the ingots made in 1880 being converted into rails, while in 1890 the percentage of rails made to ingots produced was only 53 per cent.

OPEN HEARTH AND CRUCIBLE STEEL.

The production of open hearth steel in the form of ingots or direct castings during 1890 amounted to 504,351 tons of 2,000 pounds, as compared with 84,320 tons made during 1880. In 1880 there were 25 establishments containing open hearth steel plants, located in ten States, and in 1890 there were 58 establishments containing open hearth steel plants, located in twelve States. Since 1880 the manufacture of open hearth steel has been abandoned in two States, Vermont and Rhode Island, and four States have engaged in its manufacture, New York, Alabama, Indiana, and California. During the past few years great activity has taken place in the erection of open hearth steel plants, and indications point to a still larger production of this kind of steel during the next few years.

The following table gives, by States, the production of open hearth and crucible steel in the form of ingots or direct castings, in 1880 and 1890, in tons of 2,000 pounds.

States.	Open hearth Steel Ingots or Direct Castings. (Tons of 2,000 pounds.) Year ended May 31, 1880.	Year ended June 30, 1890.	Crucible Steel Ingots or Direct Castings. (Tons of 2,000 pounds.) Year ended May 31, 1880.	Year ended June 30, 1890.
Alabama	....	300	....	....
California	....	6,004	....	....
Connecticut	....	....	2,116	1,734
Illinois	625	....	130	445
Indiana	....	1,000	....	350
Kentucky	275	....	75	....
Maryland	....	....	....	1,000
Massachusetts	9,475	13,967	140	532
Michigan	....	....	....	2,000
New Hampshire	4,621	3,700	....	....
New Jersey	450	9,656	10,492	8,843
New York	....	1,300	2,585	6,797
Ohio	24,712	61,232	360	....
Pennsylvania	36,944	406,292	60,303	64,225
Tennessee	4,000	....	....	100
Vermont	3,000	....	....	....
Total	84,302	504,351	76,201	85,536

The crucible steel industry has shown but little progress since 1880, the production in that year amounting to 76,201 tons of 2,000 pounds, as compared with 85,536 tons produced in 1890. In 1880 there were 36 establishments containing crucible steel plants, located in nine States, while in 1890 the number of establishments had increased to 47, located in eleven States. For purposes requiring special grades of steel the product of the crucible process will be always in demand, but the high cost of manufacture prevents it in many instances from successfully competing in price with the other processes mentioned.

THE BASIC PROCESS.

The first basic steel made in the United States was produced experimentally at Steelton, Pennsylvania, by

a Each Bessemer, open-hearth, and crucible steel plant is counted as separate works, although two or more of these plants are frequently embraced in a single establishment.

[1] "Scientific Writings of Joseph Henry," vol. ii., p. 435.

[2] See Mr. Latimer Clark's account of Cooke in vol. viii. of "Journal of Society of Telegraph Engineers," p. 3741, 1880.

[3] W. F. Cooke, "The Electric Telegraph: was it invented by Professor Wheatstone?" 1856-7, pt. ii., p. 87.

[4] *Ib.*, p. 95.

the Pennsylvania Steel Company on May 24, 1884, in a Bessemer converter. The beginning of the manufacture of basic steel in this country as a commercial product, however, dates from 1888, on the 28th of March of which year the first basic open hearth steel was produced at the Homestead Steel Works of Carnegie, Phipps & Company, Limited, at Homestead, near Pittsburg, Pennsylvania. Since that date the manufacture of basic open hearth steel has been continued at these works, and during 1890 this firm commenced the erection of eight additional open hearth furnaces for the manufacture of basic steel, of which number four are now in operation and the remaining four furnaces are expected to be ready for working in a short time. When completed these works will contain 16 open hearth furnaces prepared to manufacture basic steel. The manufacture of basic steel is now also regularly carried on at the Steelton Works of the Pennsylvania Steel Company, where a combination of the Bessemer and open hearth process is used. During 1890 the Henderson Steel and Manufacturing Company, at Birmingham, Alabama, produced steel experimentally by the basic process. Since the close of the year the Southern Iron Company has successfully commenced the manufacture of basic open hearth steel at its works at Chattanooga, Tennessee. The Pottstown Iron Company, at Pottstown, Pennsylvania, has also produced steel by the basic process.

In Great Britain and on the Continent the basic process has been received with great favor, and large quantities of basic steel are made annually by all the leading iron and steel producing countries abroad. The wonderful growth of the steel industry of Germany and Luxemburg during recent years has followed the introduction of this process, the iron ores of these countries being especially suited to the manufacture of basic steel.

While the basic process is applicable to either the Bessemer or open-hearth process, its use in this country in connection with the open-hearth furnace is most promising of successful results, and the indications are that the growth of the basic steel industry of the United States will be largely in this direction. The total production of basic steel in the United States during 1890 amounted to 62,173 tons of 2,000 pounds, nearly all of which was made by the basic open-hearth method, a small part being produced by the duplex process, a combination of the Bessemer and open-hearth methods.—*Census Bulletin No.* 13.

THE FRUIT GARDENS OF CALIFORNIA.

LIKE all distant countries, California has enjoyed a sort of fluctuating repute in the various reports which have brought it into notice from time to time. At one period a gold craze excites the fervid imagination of European hearers with dreams of wealth—quickly depressed again when the gold is stated to have been "overdone." At another, a wild rush is made for land, which suddenly springs up to unheard-of values, and becomes a topic of eager interest until, within a year or so, the "boom" is said to have collapsed. In their turn, railways come to the front, and visions are presented of unheard-of developments in engineering. But amid all these more transient furors there is one point in which there has seldom or never been any substantial variation; and that is that California (in particular the southern counties of the State) possesses characteristics of climate which are undeniable. Most authorities agree that, in that respect at least, Southern California is the "pick of the world." Even visitors and settlers whose experience has extended to the choicest domains of Australia and New Zealand have been heard to say that California bears the palm. And if, as is truly the case, it does literally bear the palm, it also bears at the same time other productions of the vegetable kingdom of far greater interest and concern to the agriculturist, who is now beginning to appreciate its marvelous qualifications. The extraordinary increase in the fruit production of that favored land within the last ten years is a fact that filters slowly through the 6,000 miles which separate it from England, for the reason that the markets *en route* absorb nearly the whole of the present produce before it reaches even the Eastern States of America. Our acquaintance with Californian fruits in London is confined almost exclusively to those which come to us in the canned condition; and however excellent these in quality, the full luxury of fresh fruits can hardly be conveyed by a "tin."

LUSCIOUS PEARS AND MODEL APPLES.

Nevertheless, the forerunners of the supply have reached us, now and again, as strangers; and we are beginning to ask when these luscious-looking, pale pears and model like apples will begin to come to us in greater plenty. Are there not, moreover, other products of a soil giving such evidences as these, which may be expected to grace our shop windows in due time? Undoubtedly there are; and when the American continent is traversed with certainty in four days and the ocean in six—as they will be—some of these will greet us almost with the flush of the Californian sun and the breath of its exquisite atmosphere upon them. In a climate where all gradations of temperature except the actually tropical can be selected at will for fruit growing, there are few species which will not respond abundantly to the influences of such a soil, when the locality is duly adapted to their nature.

BUSH FRUIT AND VEGETABLES.

It is remarkable that some other balmy and equable climates, such, for instance, as those of Madeira and the Canary Islands, refuse to yield some kinds of produce, among which may be named several of the common English bush fruits, and certain vegetables, as the broad bean, cauliflower, etc. But California makes no such exceptions; she is generous in all alike, and the gooseberries, currants, raspberries, and blackberries (we rather disdain, by the way, to cultivate this latter fruit in England, chiefly because we only know it as the wild blackberry of the hedgerows)—all these familiar friends, we say, can be raised on the uplands of California in a luxuriance unknown to our capricious climate.

A WORLD'S WONDER.

In Southern California, however, the orange stands *facile princeps*—that is to say, throughout all the regions best adapted to its growth. As one drives through the seemingly endless tracts of teeming orange orchards in such districts as Riverside, Colton, or Pasadena, during the "winter" months—that is, in the full swing of the orange harvest—the site will almost be allowed to rank as a world's wonder. It will be remembered that even in California the young orange tree takes five or six years before it begins to pour its fruit into the lap of the cultivator; and hence the vast plantations formed within the last decade are now adding, season after season, fresh hundreds of acres to the actual producing area.

A MARVEL OF PRODUCTIVENESS.

It has been stated on the authority of the Los Angeles chamber of commerce that there are at this moment, in that county alone, nearly 600,000 orange trees, of which more than two thirds have reached the bearing period. Compared with the whole of California, Los Angeles county is but as one of the counties of England. The total number of trees of the citrus class (including lemons, limes, and citrons, as well as oranges) in the same county is nearly 700,000. The value of this production is reckoned to net four dollars per tree, or something like 800 dollars per acre; and this from land which in some instances could have been bought out and out ten or fifteen years ago for not

1. Orange picking at Pomona. 2. An overweighted orange tree. 3. A two year old peach tree. 4. Beaumont grapes. 5. A suburban residence, Los Angeles. 6. Cluster of oranges from a thirteen year old tree.

THE FRUIT GARDENS OF CALIFORNIA—AN ORANGE PLANTATION.

much more than the hundredth part of that sum! Such are some of the financial results of the two main factors in Californian fruit growing—industry and water. Twenty years ago nearly the whole of the waters from the vast and permanent gathering ground of the Sierra Nevada range ran to waste and were lost before reaching the lands which thirsted for them, and which are now, under the influence of irrigation, beginning to unfold their treasures.

CITRUS FAIRS.

If the intending visitor to Southern California time his visit for the month of February, and will make it a point to attend one of the citrus fairs now becoming a feature of every season, he will witness a sight not likely to be effaced from his memory while he lives. The "Prize Washington Navel" on such an occasion is an orange which, if it were to appear on a hawker's barrow in Fleet Street, would speedily cause an obstruction by collecting a crowd. It will be borne in mind, however, that results like these are derived only from labor and energy. The orange grower is by no means without his cares, anxieties, and natural enemies; and his life consists of something more than sitting in a corner of his orchard smoking the pipe of peace and watching the growth.

"CANNERIES."

The "canning fruits" of Southern California share the honors with the orange. The enormous productiveness of the peach, apricot, and pear is such as to sound almost incredible to English ears if put into figures. Within the last few years vast strides have been made in the direction of introducing new and select kinds, and studying the conditions of soil and cultivation which afford the best produce. The "cannery" is another sight not easily forgotten, and the same may be said of the homesteads, where all the members of a family may be seen engaged in the duty of picking and sorting, by the bushel, peaches and apricots such as would change hands in a London shop at from sixpence to half a crown apiece. The strawberry season commences in March and lasts till November; and there is no reason why, when the variety of kinds is extended, this magnificent fruit should not be a perennial in Southern California. On the uplands and among the foot hills of the main mountain ranges, where a lower summer temperature prevails, it may be said that there is scope for an entirely fresh series of products; and it is in this respect that the country affords so remarkable a field of choice to those whose previous experience may have been gained in European cultivation.

GRAPE GROWING.

The potatoes of the higher and cooler lands have returned as much as from 100 dollars to 500 dollars per acre, and, unlike warm climate potatoes in general, possess all the prized qualities of the English tuber. The cherry, unsuited to share the home of the orange, yields an almost fabulous production, both in size and quantity, and the almond, reckoned a somewhat risky growth on the lower lands, has been known to bear in the third year. The gooseberry, currant, raspberry, and blackberry of these (comparative) highlands are described as "of immense size, fresh, plump and beautiful." Within reach by railway of a capital like Los Angeles—now a city of nearly 90,000 inhabitants—all these products find an unfailing and increasing market. Last, but by no means least, a word must be given to the attractive subject of grape growing. The extraordinary success attending the culture of this fruit—a production at once poetical and practical—is evidenced by the export of raisins from Los Angels county, which, from 2,000 boxes ten years ago, has risen to 125,000 at the present date. The total production of California has now reached no less than thirty-three million pounds of raisins, being double the quantity produced so recently as the year 1887. This vast return of course excludes the amount sold as fresh or table grapes, locally and throughout the United States, and also constituting a rapidly increasing trade. The handsome grape clusters shown in our illustration are the production of the infant colony of Beaumont, on the San Gorgonio Pass, in the southern county of San Bernardino—an upland valley possessing all the qualifications insuring an immediate future of the highest prosperity. It is in such situations, at an elevation of some two to three thousand feet above the ocean level, that the greatest variety of fruit growth is attained with the utmost security of certain success; not to mention conditions of bodily health before which even the scourges of consumption and exhausted nerves are put to flight.

WINE MAKING.

The vine grower may also include in his occupation the manufacture of wine, if possessed of sufficient capital to conduct it. There are hundreds of thousands of acres of cheap land eminently suited to the culture; and although the Californian wines are, for trade purposes, occasionally branded with European names, the consumer must admit that the best kinds afford no reason why they should not stand boldly upon their native designations, as in fact many of them do. In this case, even irrigation is not a necessity, for on many lands an excellent yield and quality are obtained without it. Already careful study has been given to the selection of suitable cuttings, and the profit of a vineyard in full bearing and well cared for may be estimated at 60 dollars or 70 dollars per acre for the choicer kinds

So far as the prospects of the intending fruit grower are concerned, the main point to be borne in mind is that no amount of glowing description—and in a land like California, many truthful descriptions must necessarily be of that nature—should lead him to expect an earthly paradise, without the earthly qualifications of industry, common sense, and experience. With these kept steadily in view and in practice, success may be reckoned as sure as any branch of human labor can achieve. Gold mines may fluctuate, and other enterprise may partake more or less of a speculative character; but fruit production is a matter of well attested facts and figures, regularly and profitably increasing year by year.—*London Daily Graphic.*

[THERAPEUTIC GAZETTE.]

ON THE NEW MEANS OF EXPLORATION OF THE DIGESTIVE FUNCTIONS.*

By Prof. DUJARDIN-BEAUMETZ,† Paris, France.

GENTLEMEN: I desire to devote this lecture to the study of the new means of investigation which enable us to obtain a truly clinical appreciation of the processes of gastric digestion in health and disease. Then we shall examine the prognostic value and utility which therapeutics may derive from these studies in the treatment of gastric affections.

In this undertaking I shall be guided not only by works published in Germany, but also by two remarkable theses, the one defended at Paris by an *interne* of the hospitals, Dr. Gaston Lyon,‡ the other having for its author a pupil of the faculty of Nancy, Dr. Georges;§ and, lastly, I have to own my indebtedness to a review which has appeared in my own journal, the

* From advance sheets, revised by the author (translated by E. P. Hurd, M.D.) Lectures delivered in Cochin Hospital, Paris, France.

† Member of the Academy of Medicine, Physician to the Cochin Hospital, Paris, France.

‡ G. Lyon, "L'Analyse du Suc Gastrique" (*These de Paris*, 1890).

§ L. Georges, "De l'Etude Chimique du Contenu Stomacal" (*These de Paris*, 1890).

Bulletin Général de Thérapeutique, and which was written by Dr. Paul Cheron.*

The digestive functions consist of two distinct processes. The one, a physical act, pertains to the movements which the muscular coat of the stomach communicates to the aliments introduced, bringing them into contact with the different points of the mucosa, then causing them to pass into the intestine. The other is a chemical act, whose end is to subject the aliments, and in particular the albuminoids, to a special modification, which renders them assimilable.

Which of these two processes is of the most consequence? According to some physiologists, the chemical act is much more important than the physical act. This is by no means the case, gentlemen, and if you could imagine a stomach without muscular contraction, digestion would be impossible; while, on the contrary (as I shall show you by and by), by virtue of the functions of the pancreas, life is compatible with a stomach almost devoid of gastric juice. But in reality these two acts are necessary, and the one completes the other; so every modification affecting either the one or the other of these acts will have for its consequence a modification in the gastric digestion, and may be the starting point of functional troubles, to which has been given the name of *dyspepsia*.

As you see, I reject the exclusive opinion of Professor G. See, who regards dyspepsia as always chemical in its origin.

We shall, then, have to examine successively the new means of investigation which enable us to understand the modifications which may take place in the physical and chemical acts of digestion. But before taking up this study, I deem it important to sum up briefly what physiology has taught us the last few years respecting the movements of the stomach and respecting the gastric juice.

Described for the first time by Helvetius, the muscular fibers of the stomach constitute in man, as you know, three layers—one of longitudinal, one of circular, and one of elliptical fibers. By their contractions these fibers impart to the stomach certain movements, which have been well studied the last few years by Schiff, Laborde, Hoffmeister, and Schultze.

Schiff maintained that these movements only take place during the digestive act. According to him, the movements consist in a simple corrugation or wrinkling of the surface of the stomach. These movements, more active toward the median part of the stomach, divide the greater curvature into two parts. Moreover, Schiff adopts the view of Beaumont, who maintained that these movements have for their object to cause the alimentary bolus to undergo certain revolutions, which bring it in contact with all points of the mucosa.

This notion of the circular movements has been combated by Laborde, who had the advantage over all his predecessors of examining the human stomach; he operated in fact, on the digestive organs of criminals a few minutes after their death.

According to him, the movements take place from the cardia to the pylorus, and from the pylorus to the cardia. Moreover, by its contractions, the stomach is divided into two pouches: the one, more voluminous than the other, corresponds to the great cul-de-sac and the greater curvature; the other to the lesser curvature. Owing to this arrangement, liquids may pass almost directly from the cardia to the pylorus by following the lesser curvature.

This disposition has been confirmed in the dog by Hoffmeister and Schultze, who compare the contracted stomach to an hour glass, with a large swelling corresponding to the cardia and a small one corresponding to the pylorus. It is in the large swelling that the chemical acts of digestion take place. But these experiments have not the value of those of Laborde, because, as Collin has remarked, each animal species has special stomachal contractions, and we cannot, from comparison with the contractions in animals, form conclusions as to the mode of contractions in man.

We can, moreover, without resorting to experiments and without laying the stomach bare by dissection, examine these contractions clinically. In fact, in patients affected by dilation of the stomach, with thickening of the muscular wall, these movements of the stomach are very clearly perceived, and you have only to apply cold in order to see them. You will then witness a wavy movement of the gastric walls, affecting alternately the greater tuberosity, then the pyloric region; and while the one lets itself become distended, the other contracts; thus there are formed elevations and depressions quite appreciable to the naked eye. These movements present a real alternation, comparable in a certain measure to what takes place in the auricles and ventricles of the heart, and thus you have a rhythm of the stomach as well as a rhythm of the heart.

Much more complex is the study of the gastric juice, and you will see that, notwithstanding the numerous works that have been written on this subject, there remain still many obscure points connected with this question.

I need not recall to your minds the structure of the gastric mucous membrane, or of the glands whose secretion constitutes its principal function. I must, however, tell you that the view of Kolliker, that there is an abrupt line of demarkation between the pepsin glands, occupying the great cul-de-sac of the stomach, and the mucous glands surrounding the pylorus, is no longer tenable; and since the labors of Haidenhain, Rollet, and Ebstein, it is now known that there is an intermediary zone, where there are both mucous glands and pepsin glands.

If there seems to be agreement respecting the mucous glands, which are characterized solely by superficial cells, there is not the same agreement respecting the pepsin glands, which contain at the same time voluminous cells with large nuclei and certain cells surrounding the orifice of the glands, and which are called *border cells*. In fact, some have maintained that the principal cells (or the large cells) secrete exclusively the gastric juice; others affirm that this role belongs exclusively to the border cells. Lastly there is a third doctrine, which affirms that the gastric juice is secreted both by the border cells and the large cells. I pass now to the study of the gastric juice.

That which characterizes essentially the gastric juice is its extreme acidity. This is one of the most striking facts connected with this secretion. There has been much discussion as to the nature of the acid, some maintaining that it is lactic, others hydrochloric acid.

To-day there is general agreement as to the following facts: There exist in the normal state in the gastric juice lactic acid and hydrochloric acid; but the lactic acid is always the product of digestion, while the hydrochloric acid is the acid of the gastric juice, and appears in this secretion at the moment of the entrance of the food into the stomach. The researches of Ewald are in this respect absolutely demonstrative.

I do not speak of the opinion of Poulet, of Plancherles-Mines, who has insisted that this acid is hippuric; this view is not held by any physiologist. So, then, hydrochloric acid is the normal acid of the gastric juice. Is it free or is it combined with other products? Here widely diverging views have been put forth.

Ewald, as well as Hayem, has maintained that the acid is not free, and that it is combined with the various albuminoid substances which are in contact with it. At the same time, Ewald rejects the hypothesis of Richet, viz., that the hydrochloric acid is combined with leucin, this substance, like tyrosin, being always a product of the decomposition of the ingesta.

Hayem,* in continuing his interesting researches with Winter on the stomachal chemism in the normal and pathological states, thinks that the hydrochloric acid is combined with albumen in the gastric juice in the state of hydrochlorate of the amide acids. These amide acids result from a breaking up of the primitive albuminoid molecule.

It has also been a matter of dispute whether the stomach when empty secretes gastric juice, and Peck affirms that this secretion ceases during fasting, or is so much diminished that it may be considered as *nil*.

Besides the hydrochloric acid, the gastric juice contains two ferments—pepsin and the lab-ferment, or pexine. I shall say but little about pepsin. We know that it transforms albuminoids into peptones, but, despite numerous researches made on this subject, we are ignorant of the true nature of these peptones. We know only that to each kind of albumen correspond special peptones, and, since the researches of Heninger, there is pretty general agreement in considering these peptones as hydrates of albuminoid matters.

The lab-ferment or pexine is a substance which causes the coagulation of milk, and those of you who would like to know more about this pexine would do well to consult the thesis of Dr. Pages.†

The new microbial theories, for which we are so largely indebted to Pasteur, have but little modified our notions as to these two ferments—pepsin and pexine. If Duclaux and Vignal have shown that the buccal cavity contains a great number of microbes, whose effect is to peptonize albuminoids, Dastre, on the other hand, has demonstrated that by sterilizing gastric juice we do not destroy, though we attenuate, its digestive power considerably, so that we are warranted in saying that certain microbes are favorable to peptonization.

As for the origin both of the acid and of the ferment of the gastric juice, all is obscurity. The old theory of peptogenous substances, so much in vogue several years ago, seems to be abandoned, and there is a general admission that the stomach does not directly form pepsin, but a body called *pepsinogen* or *propepsin*, which then transforms itself into pepsin.

As for the hydrochloric acid, it is believed to come from the decomposition of the chlorides contained in the blood, and the recent researches of Professor Hayem tend to justify this view.

After these preliminary observations, I come to the study of the new processes which enable us to understand both the movements of the stomach and the chemism of this organ. Let us begin with the methods of investigating the movements of the stomach.

I have just told you that we may in certain cases observe *de visu* the movements of the stomach through the abdominal walls. But these are only exceptional cases, and to judge of the contractility of the stomach we must make use of processes more or less complex; the most simple and advantageous is most certainly that of Leube.

Basing himself on physiological data, Leube maintains that seven hours after a normal meal the stomach, in the healthy state, should be entirely empty. It is sufficient then to give to the patient a meal of meat, eggs, and bread, then to practice lavage of the stomach seven hours after this meal, and you will find the stomach devoid of food.

Klemperer has proposed a process derived from the same method, but much more complex. It is called the *oil process*. It is based on this fact, that, in the physiological state, seventy to eighty grammes of oil pass from the stomach into the intestine in two hours. The operator then introduces, by the aid of the œsophageal sound, one hundred grammes of oil; then, with the stomach pump, he aspirates, at the end of two hours, the contents of the stomach. The stomach is next washed out with water, which is allowed to settle, the oil is dissolved out by ether, and a calculation is made of how much oil has passed into the intestine. This is a process which is much more complicated than that of Leube, and does not seem to present any advantage over the latter.

The third means is based on chemical reactions. There is a substance to-day very much used in surgery—salol—which results from the combination of salicylic acid with phenic acid. One of my pupils, Dr. Lombard, has shown all the therapeutic applications which may be made with salol.‡

This body in the presence of alkalies is decomposed into phenic acid and salicylic acid. Ewald has utilized this property in order to determine the contractility of the stomach. He administers one gramme of salol to the patient, and examines the urine to find at what moment salicylic, or rather salicyluric, acid appears in that secretion. In the normal state this acid makes its appearance at the end of half or three-quarters of an hour. When there is a delay, Ewald affirms that this is due to the fact that the stomach, through sheer inactivity, has not let its contents pass into the intestine.

Certain objections may be made to this test. In a thesis which bore a prize from the faculty, and which was written by one of my best pupils, Mlle. Dr. Chopin,* it appears that the elimination of salicylic acid depends in great part on the condition of the kidney, and it may be considerably retarded in old people. On the other hand, it depends on the nature of the meal, and especially on the nature of the liquid ingested. We may cause the appearance of the salicylic acid to vary considerably, as Bourget has shown.

The same objections may be made to the modifications of Ewald's method proposed by Hubert, who examines the urine not only to ascertain at what moment the salicylic acid appears there, but also to find out the time when the reaction disappears, a period quite remote from that of the ingestion of food in persons with inactive stomachs.

Hence I am disposed to make little account of these chemical processes, and adhere exclusively to the method of Leube. I come now to the clinical means put in use for the study of the gastric juice.

All these clinical means are exclusively based on the employ of the stomach siphon, furnished or not with a pump to aspirate the liquid from the stomach. I have already in my "Alimentary Hygiene" set forth the processes heretofore employed to obtain gastric juice.† All these processes are abandoned save that of the pump, which is Collin's invention, and is a model of its kind. When you have no pump, you can use the simple stomach tube, making a siphon of it. But before endeavoring to collect the gastric juice, it is necessary to give the patient a repast, called the *trial meal*.

Many trial meals have been recommended. Thus Riegel, Gluzinski, Jaworski, Boas, Ewald, Ritter, Hirsch, and Professor See have each proposed a trial meal.

From a clinical point of view, two only need be retained, those of Ewald and G. See. That of Ewald is almost exclusively employed in Germany, where it bears the name of *probefruhstuck*. It consists of a little white bread weighing thirty-five grammes (about an ounce), of a tumbler and a half (three hundred grammes) of water, or of light tea, without milk or sugar. This meal is given in the morning, on an empty stomach, and the gastric juice is examined one hour after the ingestion of the food.

See gives a meal which is more complex, composed of meat (sixty to eighty grammes) hashed very fine, of white bread (one hundred to one hundred and fifty grammes), and of a glass of water. He recommends to the patient a prolonged mastication. The examination of the gastric juice is made two hours after the ingestion of this meal.

Georges maintains that this meal gives rise to the production of lactic acid. Hence he prefers Ewald's test meal, to which he adds two eggs in the shell. It is well understood that the aspiration made with the pump should not be too energetic, and it suffices to obtain from twenty to twenty-five cubic centimeters of gastric juice in order to practice the examination. The gastric juice is filtered, then is acted upon by the reagents, of which I will now speak. Almost all these tests (if not all) are based on the modification which the hydrochloric acid effects in the divers coloring materials obtained from coal tar, and I will begin by the reagent which has been longest in use—methyl violet.

It was Laborde and Dusart,‡ who, in 1874, sixteen years ago, were the first to propose methyl violet for the study of the modifications of the gastric juice. It is true that they applied it rather to physiological than to clinical studies. Since then Maly has taken up again the method of Laborde, and in 1887 applied it to practical use.§

To apply this test you thus proceed:

Into fifty cubic centimeters of water let fall three or four drops of methyl violet, called *Paris violet;* then pour into the solution the gastric juice which you are to examine, and if hydrochloric acid be present, the violet will turn to deep blue. An amount of hydrochloric acid equal to 0·5 per thousand is needed to produce this reaction.

Lactic acid also gives the same coloration, but it must be very concentrated (at least ten per cent.). The presence of peptones, in the proportion of four per cent., prevents the reaction from taking place, even when hydrochloric acid exists to the extent of one per thousand in the solution.

The second process is that of tropœoline, recommended by Leube, and in 1884 I published several articles, making known the advantages which may be obtained from this test.‖

This is the way to test gastric juice by tropœoline, or the Poirrier orange, No. 4: Into a watch glass, placed on a white piece of paper, or other white surface, you pour one of the following solutions, either a small quantity of an aqueous solution of tropœoline, one per cent., or of an alcoholic solution, containing 1 part of alcohol to 3 parts of distilled water, with enough tropœoline to make a centesimal solution; then to the liquid in the watch glass you add a part of the gastric juice to be examined, and if there be hydrochloric acid present, the liquid assumes a very characteristic carmine red color, which is in striking contrast with the normal yellow color of the tropœoline solution.

Like the methyl violet, this reaction may also be obtained with lactic acid, but a large proportion is needed, as much as two per thousand; this test is very sensitive, and is but little influenced by peptones. Hence it is that Georges places it at the head of the tests to be employed.

It is also on a change of color that the tests with Congo red and "brilliant green" are based. In applying the first reagent, test papers saturated with the pigment (or a solution of the pigment) may be used; these, under the influence of hydrochloric acid, pass from a clear red to a blue color. To obtain this reaction, one milligramme per thousand of hydrochloric acid is sufficient. There would be required as much as 1·20 grammes per thousand of lactic acid in order to

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* Paul Cheron, "On the Chemical Alterations of the Gastric Juice and their Treatment" (*Bull. Gen. de Ther.*, t. cxviii., pp. 145, 215, 264).

* Hayem and Winter, "Researches on the Stomachal Chemism in the Normal and in the Pathological State" (*Bull. Med.*, 1889).

† "Researches on Pexine" (*Thes de Paris*, 1888).

‡ Lombard, *Thes de Paris*, 1887.

* G. Chopin, "On the Elimination of Salicylic Acid" (*Thes de Paris*, 1889).

† Dujardin-Beaumetz, "Hygiene Alimentaire," 1889, p. 201.

‡ Laborde, "The Coloring Matters applied to the Research and Determination of the Free Acid of the Gastric Juice" (*Bulletin General de Therapeutique*, t. cxii., p. 80, 1886).

§ Richard Maly, "Untersuchungen uber die Mittel zur 'Saure Bildung in Organismus und uber einige Verhaltnisse der Blutserum" (*Zeitschrift fur Physiologische Chemie*, t. i. p. 174, 1887).

‖ Dujardin-Beaumetz, "On the Diagnostic Value of the Processes for the Recognition of the Acidity of the Gastric Juice" (*Societe Medicale des Hopitaux*, December, 1884, and *Gazette Hebdomadaire*, December 4, 1884, p. 804).

give the same reaction. Georges regards this as an excellent test.

The "brilliant green" test was proposed by Professor Lepine. He makes use of a two per cent. solution, and the presence of the acid makes the mixture pass from a greenish blue to a deep green. The inconvenience lies in the difficulty of appreciating the passage from a greenish blue to green.

Lastly, Gunzburg's test, especially vaunted by Germain See and his pupils, is the most sensitive of all. It will reveal the presence of one-twentieth per thousand of hydrochloric acid, only the process is quite complex, and heat is needed in order to bring out the reaction; so that this test is not so well adapted for clinical test as some others. This is the composition of this reagent:

℞ Phloro-glucine, 2 grammes;
Vaniline, 1 gramme;
Alcohol at 80°, 100 grammes. M.

This solution is of a reddish yellow color.

Into a porcelain capsule you will put ten or twelve drops of the gastric juice to be examined, and add three or four drops of the reagent. Then you will heat the mixture slightly, taking care not to raise the temperature above 38° to 40° C.; there will then appear along the borders of the capsule a cinnabar red coloration.

If this reagent is extremely sensitive, it presents the serious disadvantage that its reactions are masked by the peptones and albuminoid bodies. Hence I think that we should trust chiefly to the tropœoline and methyl violet tests, and only make use of the Gunzburg test in exceptional cases.

In certain circumstances it is desirable to test for lactic acid. For this there is but one regeant, viz., that proposed by Uffelmann. The solution must be extemporized for the occasion, according to Lyon's recommendation. Drop into a mixture of twenty cubic centimeters of distilled water and ten cubic centimeters of phenic acid (four per cent.) two or three drops of the *liquor ferri perchloridi*. The mixture takes on an amethyst hue, which turns to bright yellow in presence of lactic acid.

There remains yet the process for testing the acidity of the gastric juice. I shall not speak of the methods of Leon and of Winter, which are laboratory methods, and shall only mention the clinical processes. The following is a convenient method: Take ten cubic centimeters of gastric juice, and add a few drops of a solution of phenol phthaleine, which has the property of changing to a lively red in the presence of a free alkali. Then add drop by drop a standard solution of soda—one-tenth—and make your calculation on the basis that one cubic centimeter of the solution neutralizes 0·003646 of HCl. In the normal state it takes from four to six cubic centimeters of this decimal solution of soda to produce the reaction.

Lastly, it is well to test the digestive power of the gastric juice by practicing with it artificial digestions. For this purpose, you will put into a test tube five cubic centimeters of gastric juice and a little block of albumen—from five to six millimeters square. Place the whole in a stove, and expose it to a temperature of 38° to 40° C. You may make at the same time, for purposes of comparison artificial digestions by the aid of pepsin.

But in order to give you an idea of the minutiæ of the processes employed in Germany to test the digestive power of the gastric juice, allow me to quote the method counseled by Gunzburg to ascertain the chemical power of the stomach. This method is based on the presence of iodide of potassium in the saliva, when this salt has been absorbed into the circulation.

Gunzburg takes a pastille of iodide of potassium and incloses it in an envelope of caoutchouc, which is closed by means of threads of fibrin that have been preserved in alcohol. These little pastilles are dipped into glycerin; then one of them is taken and placed in a gelatin capsule, and the patient is made to swallow it. Then the saliva of the patient is examined, and the moment noted when the presence of iodine is revealed by the starch test. By the time which has elapsed, one is able to decide as to the digestive value of the gastric juice, for this fluid must first destroy the threads of fibrin before the pastilles of iodide of potassium are set free.

I do not know whether the method of Gunzburg is much employed in Germany, but it must be admitted that in France it is really impracticable. It must be confessed, in fact, that the patient and the physician will need a great deal of patience in order to subject for several hours, and from moment to moment, the saliva of the patient to a chemical examination which shall reveal the presence of iodine, and when the iodine is detected, nothing is solved thereby, for the pastille may have passed into the intestine before its threads are dissolved. Therefore, I think that it is just as well to reject these too complicated methods, which belong rather to the laboratory than to the department of clinical medicine.

You are now in possession of three orders of means which will enable you to detect the presence of free hydrochloric acid, the presence of lactic acid, the acid value of the gastric juice, and, lastly, its digestive power.

With all these methods, can you dispense with the clinical examination, and on these data alone establish your diagnosis and your therapeutics?

No, gentlemen; and when you come to realize all the time and pains and care which these chemical researches necessitate, and the meager results which they bring, you will be tempted to say that the mountain has labored and brought forth a mouse. In fact, as Georges has well said, the diseases of the stomach, from a chemical point of view, group themselves into two classes—those where there is hypersecretion of hydrochloric acid and those where there is hyposecretion.

In the first group there is but one disease, viz., simple ulceration of the stomach; in the second are grouped all the other affections—gastritis, dilatation of the stomach; in a word, affections the most widely different. Hence, Hayem, in his recent researches, has shown that the presence of free hydrochloric acid does not enable one to decide respecting the diagnosis of the affections of the stomach, since its presence is an exceptional fact.

Do I mean by this that we must abandon these researches? By no means. These researches furnish us a complement of information which enables us to confirm, in a certain measure, the diagnosis to which we may have arrived by the other and really chemical means. But it is always the latter which should have the first place, and the study of the treatment of the divers diseases into which I am about to enter will be an absolute proof of what I maintain, and this proof I shall endeavor to make as complete as possible when I take up, as I intend to do in the next lecture, with the help of all the new light of modern research, the consideration of cancer of the stomach and its treatment.

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